

TECHNOLOGIES FOR IMPROVED REFINERY GAS UTILIZATION

NPRA 2010 MEETING PHOENIX AZ

AM-10-178

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Abstract

The trend of processing more heavy and sour crudes, the shift in demand away from gasoline towards more distillate, and more stringent fuel qualities change the fuel and hydrogen balances in most refineries. Finding the right solution to managing fuel gas and hydrogen requirements has become essential for refineries to remain profitable. With a combination of proven and new technologies, Praxair is well positioned to address refinery “fuel long” situations. The refinery gas value is higher for hydrogen generation than for generating power and slightly lower than the value for using it as chemical feedstock. Cryogenic processing of refinery fuel gas to recover valuable products (hydrogen and LPG) is also a viable option, especially when it is integrated with post-purification technologies (e.g. PSA). Praxair has also developed a patented refinery gas processor based on a short contact time catalyst that can reliably process refinery gas and convert it into SMR suitable feed. We will discuss how different technologies are suited to different refinery gas streams and how to optimize recovery given differing energy and capital cost constraints.

1 Introduction

Refinery fuel gas management has been recognized as a key element for optimum refinery operation. As higher quality fuels are mandated, refineries face pressure to increase their processing intensity in order to remain profitable. In addition, refineries are seeking to increase their ability to process heavy and sour crude in order to achieve needed operational flexibility. These two main trends cause the demand for hydrogen to rise due to the increasing severity of hydroprocessing operations required to process the heavy and sour crude and yet meet the stringent product quality requirements. This requires securing additional hydrogen capacity, either from on-purpose hydrogen production (on-site or third-party producers), or through hydrogen optimization and recovery. Also, increased processing severity has caused increased refinery gas (i.e. H₂, C₁-C₅) production, which exceeds in many cases the capability of the refinery to use it as fuel, forcing the refiner to change refinery operations to meet fuel gas constraints, produce and vent unneeded steam, flare fuel gas, or sell fuel at a discount. Furthermore, there is a shift in demand away from gasoline and towards more distillate. Some refiners are choosing to curtail their naphtha reforming capacity to address this market need. As a result, a significant source of hydrogen in a refinery is lost, thus widening the gap between hydrogen supply and demand. Refiners are likely to find themselves in a position with more fuel gas and less

hydrogen, which has generated an increased interest in fuel gas management projects.

Managing the fuel gas system provides multiple benefits:

- Increased operational flexibility and profitability
- Optimized hydrogen sourcing
- Reduced fuel demand
- Improved fuel gas quality, burner control and emissions
- Decreased CO₂ emissions

There are obvious direct benefits to upgrading the refinery fuel gas and implementing hydrogen recovery systems, but there is also an indirect benefit to raising the overall hydrogen system purity. Rather than routing low-to-mid purity hydrogen to hydrotreaters, greater value from these process streams can be obtained by upgrading the hydrogen quality. Higher hydrogen purity will increase the purity of the recycle stream and reduce fuel gas production in the hydrotreating units. This can lead to both improved yields and performance or longer catalyst run lengths in hydrotreating units.

Another indirect benefit of better fuel gas management is that it is an enabler for other energy reduction projects. These projects generally lower the demand for fuel gas in various refinery operations, but the lack of an outlet for the “saved” fuel gas may become an impediment in the implementation of the energy conservation projects. Conversely, such projects achieve higher benefits if

the “saved” fuel gas is utilized in a productive manner.

Refineries that are “fuel long” generally seek to export energy in the form of refinery fuel gas or look for other ways to extract value from the fuel gas system. Pressure Swing Adsorption (PSA) and cryogenic based separation methods are commonly used to recover hydrogen and hydrocarbons from the fuel gas. Another approach is to use the gas as fuel for electric power generation, but this is usually the lowest value alternative. Fuel gas can also be used as feed to hydrogen plants (Steam Methane Reformers (SMRs)). Generally such approaches are

applicable to selected high-hydrogen, low-olefin streams (PSA systems or SMRs), or require chemical facilities nearby to use the recovered products (olefin recovery with cryogenic systems). Praxair believes that the value created by using refinery gas for hydrogen generation is higher than the value for generating power and slightly lower than the value for using it as chemical feedstock (Figure 1). Power generation from steam at refinery conditions is disadvantaged compared to power from other sources which tend to use higher efficiency combined-cycles.

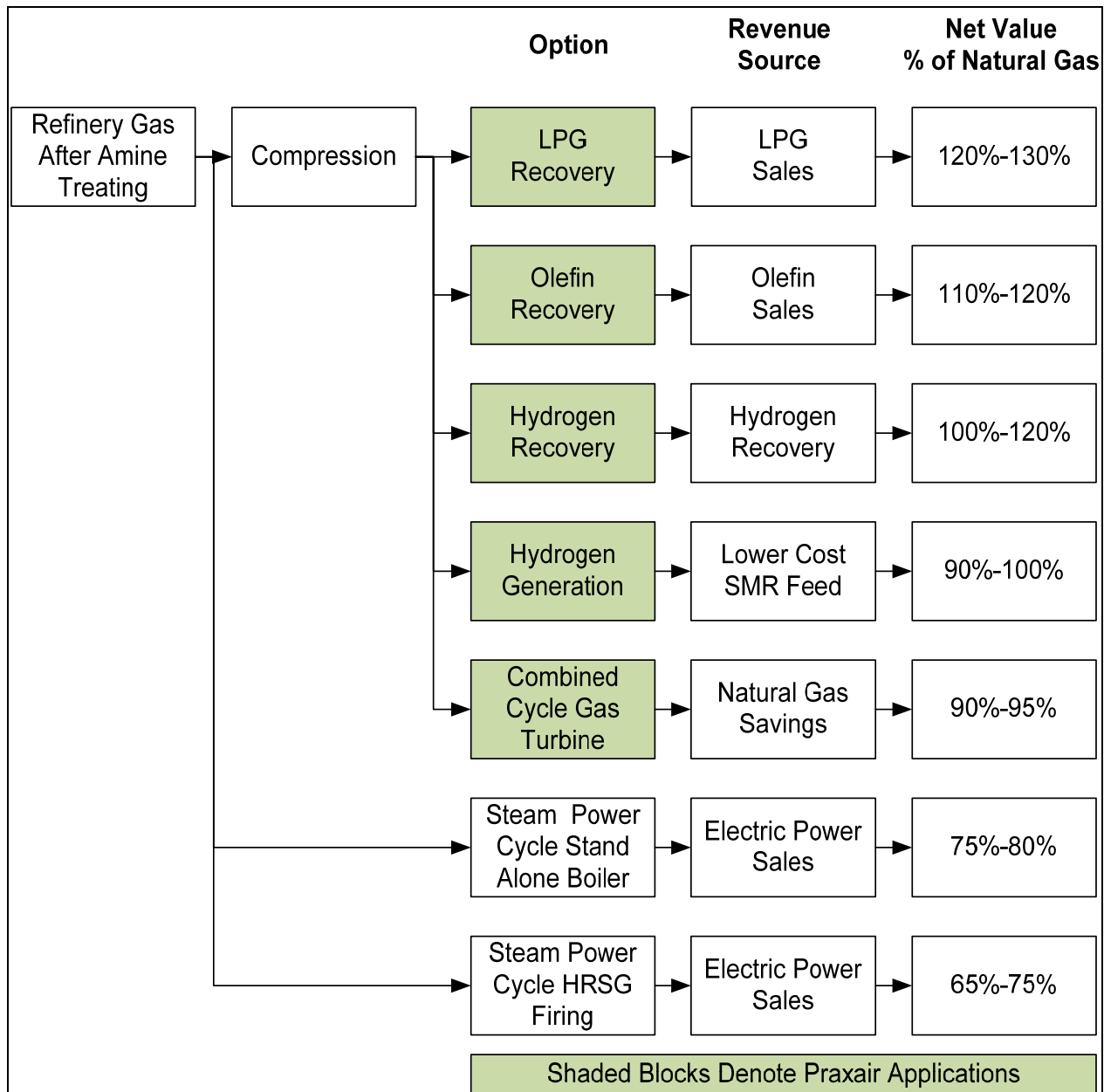


Figure 1: Refinery Gas Value for Different Applications Expressed as a % of the Value of Natural Gas

Using refinery gas as a feedstock for hydrogen production has high potential but available pre-treatment technologies are generally based on natural gas processing [1] and are unable to cope with the quality and characteristics inherent to refinery fuel gas. Refinery gas is typically highly variable with high olefin, C₂₊ and sulfur content which makes it difficult to process in SMRs. Similarly, refinery fuel gas is unsuitable as a feed to gas turbines with Dry Low NO_x (DLN) combustors. The typical DLN burner fuel specifications for hydrogen and C₂₊ are 10% and 15% maximum, respectively. Refinery fuel gas likely has hydrogen and C₂₊ content that exceeds these limits. Furthermore, olefins contained in the fuel gas tend to form soot and a minimal compositional variation is required to maintain NO_x performance of the DLN combustors. A common approach to get around these limitations is to use fuel gas as a supplemental fuel to the heat recovery steam generators (HRSG) in gas turbine cogeneration plant or as a fuel to the SMR furnace. However, this approach limits the amount of fuel gas that can be used and/or the value obtained from use of the fuel gas.

To address some of these challenges, Praxair has developed a suite of solutions for refinery fuel gas management which can be tailored on a site-specific basis. One approach that Praxair takes to fuel gas management is integration with hydrogen production. This can be done by simple hydrogen recovery, fuel gas integration as feed for on-purpose hydrogen generation, or a combination of the two. Another approach is hydrogen and LPG recovery via cryogenic processing. This offers a solution to both hydrogen shortages and excess fuel gas, and when integrated with hydrogen purification by PSA, it offers both incremental hydrogen and the benefit of high purity.

In addition, Praxair is developing innovative approaches to fuel gas management that help refineries run as efficiently as possible. Praxair

has developed a patented Refinery Gas Processor (RGP) based on a short contact time catalyst that can condition a wide array of refinery gas compositions for use as SMR and gas-turbine feed. RGP permits a significant increase in the refinery gas to natural gas ratio for SMRs or for gas turbines with DLN combustors. RGP is particularly suited to fuel gas streams with a high olefin content and varying quality. Praxair's RGP technology creates value in a refinery by making it easier to use problematic fuel gas streams in SMRs and gas turbines.

2 Praxair Solutions for Fuel Gas Management

2.1 Integration with Hydrogen Production

There are different degrees of integration between hydrogen production and fuel gas management. Praxair has three distinct designs linking fuel gas management and hydrogen production that have been put into practice. The first design is a simple recovery of hydrogen. Figure 2 shows a block diagram of an installation that Praxair operates at a large refinery. In this case, the refinery was looking to recover hydrogen from streams that would otherwise end up in the refinery fuel header. The PSA and compression system allows the refinery to recover up to 40 million standard cubic feet (60 °F and 14.7 psia) per day (MMSCFD) of hydrogen for use in place of on purpose hydrogen. Praxair and the refiner worked together to identify refinery streams with a hydrogen content that would make hydrogen recovery economically feasible. Generally, a PSA system works well with an aggregate feed-stream with at least 60% hydrogen by volume. Praxair optimized the feed, product, and tail gas compression design characteristics to minimize the lifetime power costs, optimize PSA performance, and minimize the capital for the installation. The tail gas from the PSA system is

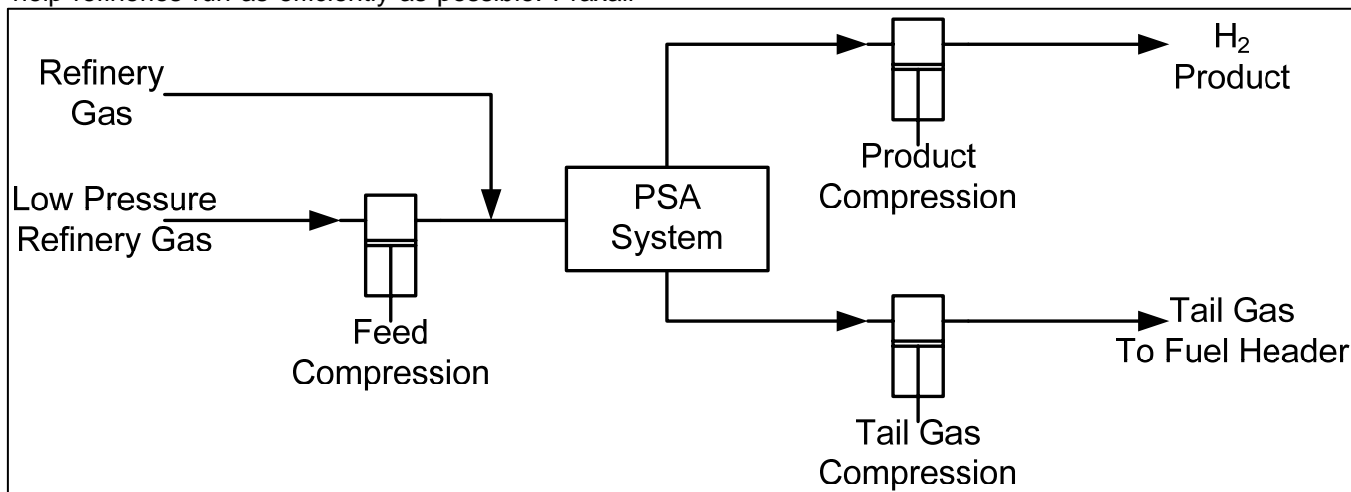


Figure 2: Refinery Gas PSA Configuration

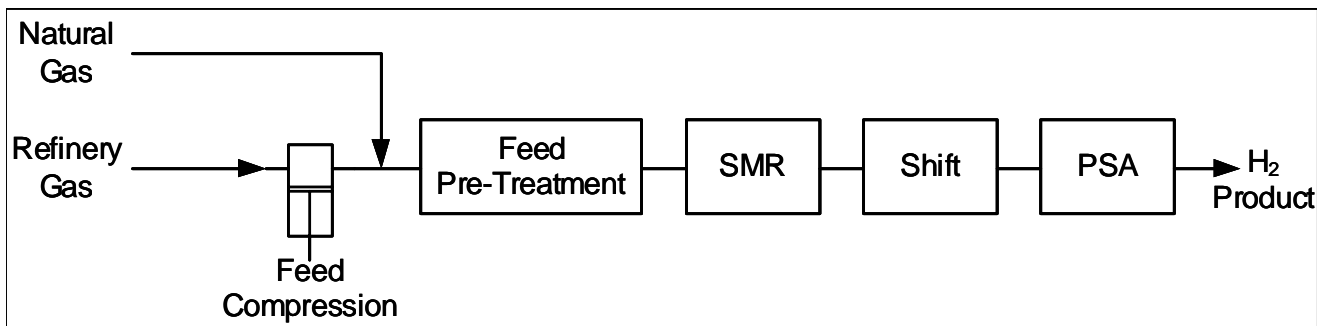


Figure 3. Refinery Gas as SMR Feed

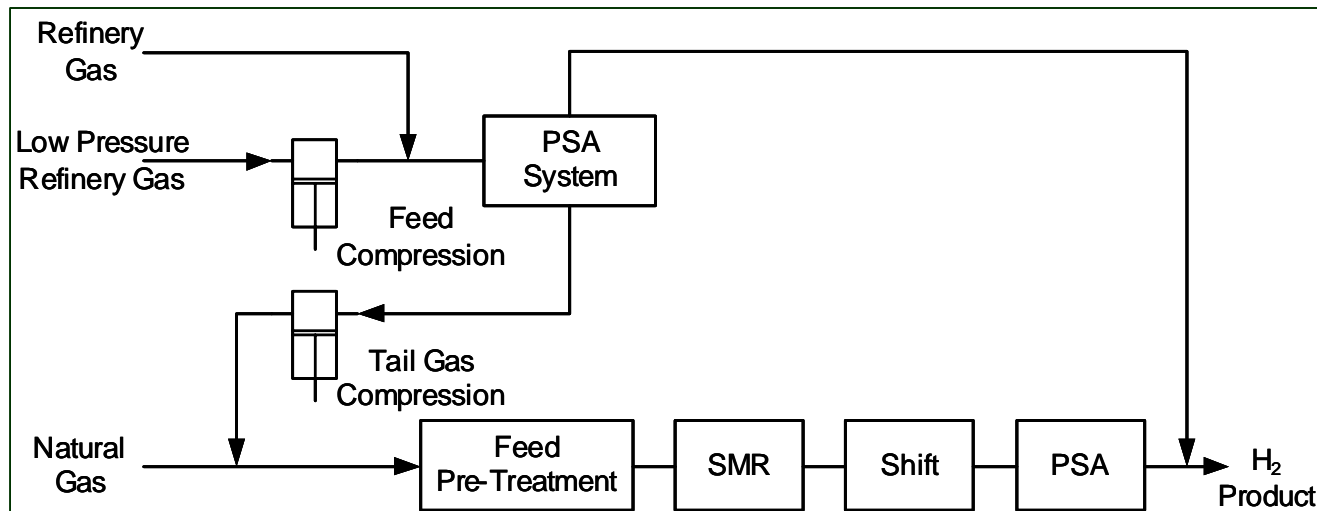


Figure 4: Integrated Hydrogen Recovery and Generation from Refinery Gas

compressed and returned to the refinery fuel system, and the product hydrogen is compressed and delivered to a high pressure hydrogen consumer in the refinery. All three compression services are designed on a common reciprocating compressor frame. Praxair installed three 50% compressors to ensure high reliability.

Simple recovery reduces the amount of on-purpose hydrogen that may be required to satisfy incremental demand. Other designs can integrate refinery streams into on-purpose hydrogen production. Praxair has implemented a design where refinery gas can be used as a feedstock to a SMR hydrogen plant, with supplemental feed in the form of natural gas. In this specific example, the refinery gas feed is a light hydrocarbon stream with approximately 25% hydrogen by volume and 4% olefins. The refinery gas makes up approximately 45% of the total SMR feed, with the balance natural gas and contributes 42% of the total feed plus fuel to the facility. This configuration is shown in Figure 3.

In addition to reducing the energy content required for on-purpose hydrogen production, this design also allows the hydrogen in the refinery gases, which is too low in concentration for

economic PSA recovery, to be recovered the steam methane reforming process.

In the event that hydrogen recovery makes economic sense, but does not provide the total amount of additional hydrogen required by a refiner, a hybrid scheme of PSA recovery integrated with on-purpose hydrogen production can be an attractive solution. Praxair is currently installing a facility that recovers hydrogen from a collection of refinery gases, and then uses the PSA tail gas as a SMR feedstock supplemented with natural gas as shown in Figure 4. This system leads to a high recovery of the hydrogen contained in the refinery gases because the PSA tail gas containing unrecovered hydrogen is further processed as SMR feed. In this case, the refinery gases again contribute 45% of the total SMR feed and 42% of the feed + fuel to the facility.

Recovering hydrogen from refinery streams decreases the need for on purpose hydrogen and can also reduce greenhouse gas emissions. Recovering 1 MMSCFD of hydrogen from the fuel header and displacing 1 MMSCFD of on purpose generation from a typical modern SMR will avoid the generation of approximately 22 Metric Tons of CO₂ (without fuel replacement of the

recovered hydrogen). If the recovered hydrogen displaced on-purpose hydrogen from an older and less efficient SMR, the avoided CO₂ generation is even higher.

The biggest obstacle to using refinery gases as SMR feedstock is the feed pretreatment that is required upstream of the reforming catalyst. The feed treatment exists primarily to reduce sulfur levels in SMR feed-streams, but conventional feed treatment systems have limitations, such as olefin content, that can restrict the amount of refinery gas that can be processed by an SMR. Diluting refinery gases with natural gas can be a convenient solution. However, there are cases where dilution may not be possible, such as a case of high amounts of available refinery gas, but low on-purpose hydrogen demand. In these cases, additional investment would be required to make a conventional hydrogen flowsheet suitable for operation with refinery gas as a feedstock.

2.2 Hydrogen and Hydrocarbon Recovery with Cryogenic Systems

Recovering hydrogen and heavier

hydrocarbons from refinery fuel gas can help refineries with both hydrogen and fuel costs. Cryogenic separation is typically viewed as being the most thermodynamically efficient separation technology. The higher capital cost associated with pre-purification and the low flexibility to impurity upsets has limited its use in hydrogen recovery. However, it would be one of the first choices when higher value can be obtained from other products (olefins, LPG), especially when BTU removal from the fuel-gas system is of high priority.

2.2.1 HLRU Process Description

The traditional process would involve a multi-stage, multi-product cryogenic separation system. The HLRU technology (Hydrogen and Liquids Recovery Unit) developed by Praxair (Figure 5) uses a simpler one or two-stage partial condensation process, followed by PSA purification. Auto-refrigeration provides the necessary cooling duty. This process allows economic hydrogen recovery from low purity streams (as low as 30% H₂) - offering both incremental hydrogen, and the benefit of high purity hydrogen. If BTU removal is also of

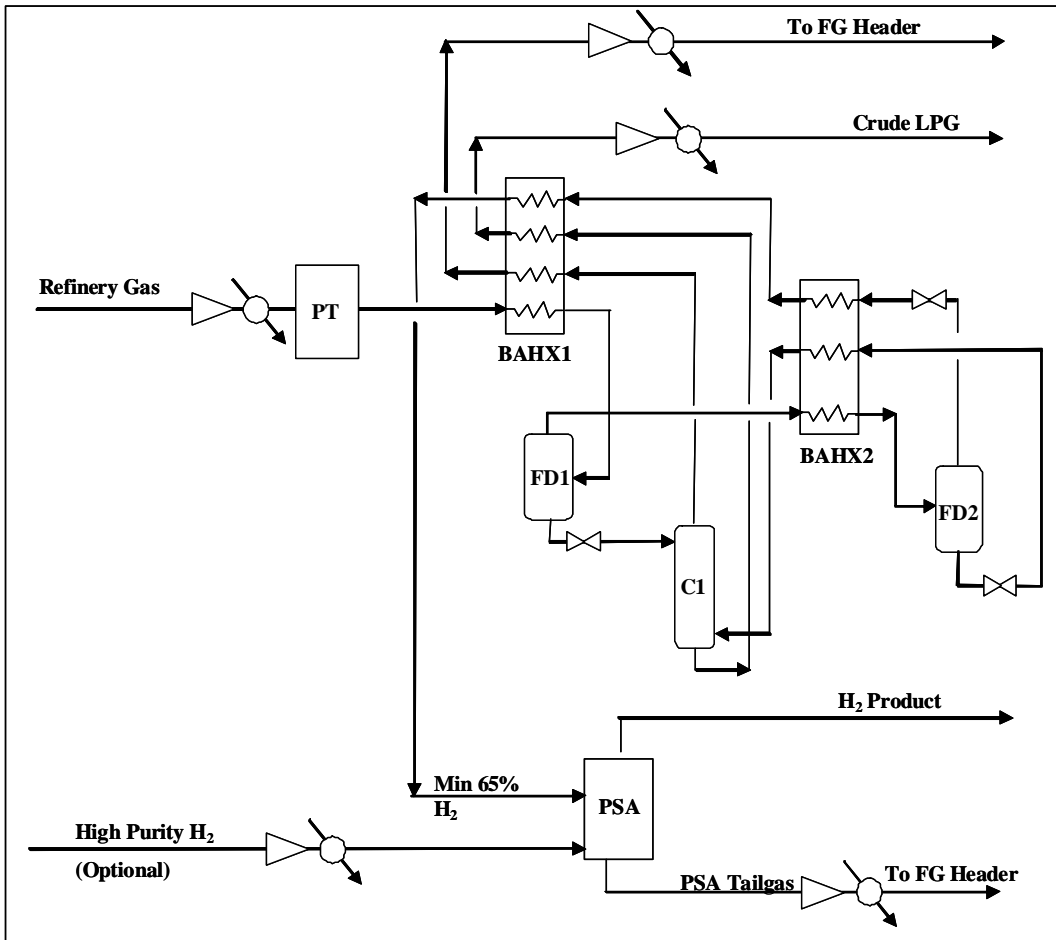


Figure 5: Integrated Cold Box and PSA Process for H₂ and Crude LPG Recovery

Table 1: Feed and Product Stream Summary

Name	HLRU-Feed	HLRU H2	LPG Product	H2 Product	HLRU Fuel Gas	PSA TG to Fuel	Fuel Gas
Molar Flow (lbmole/h)	4,941	3,522	558	2,126	861	1,395	2,256
Vol. Flow (MMSCFD)	45.0	32.1	5.1	19.4	7.8	12.7	20.5
Mass Flow (lb/hr)	68,300	23,643	23,760	4,287	20,897	19,355	40,253
Liq. Vol. Flow @ Std Cond. (barrel/day)			3,291				
Composition (mole fractions)							
H2	0.501	0.686	0.000	0.9999	0.068	0.208	0.154
Methane	0.270	0.291	0.012	0.0001	0.350	0.736	0.588
Ethane	0.140	0.012	0.370	0.0	0.513	0.031	0.215
Propane	0.055	0.0	0.391	0.0	0.062	0.0	0.024
i-Butane	0.014	0.0	0.118	0.0	0.004	0.0	0.002
n-Butane	0.008	0.0	0.065	0.0	0.001	0.0	0.0
i-Pentane	0.002	0.0	0.014	0.0	0.0	0.0	0.0
n-Pentane	0.002	0.0	0.020	0.0	0.0	0.0	0.0
n-Hexane	0.001	0.0	0.011	0.0	0.0	0.0	0.0
Nitrogen	0.007	0.010	0.0	0.0	0.002	0.025	0.016

interest, a “crude” LPG stream is obtained in a two-stage partial condensation process.

Screening studies at several refineries proved that hydrogen upgrading via partial condensation can be economically attractive, although economics will change on a site specific basis, depending mostly on gas composition (especially N₂ and heavy hydrocarbon concentrations), impurities levels (CO₂, NO_x, benzene, dienes), fuel header pressure levels and site tie-ins.

Figure 5 presents the basic configuration of a two-stage partial condensation process for hydrogen recovery from refinery gases, with post purification via PSA and crude LPG recovery. The keys steps in this process involve first compressing and pre-treating the crude refinery gas (RG) stream before chilling (in BAHX1) to an intermediate temperature (-60 to -120 °F). This partially condensed stream is then separated in a flash-drum (FD-1). The liquid stream from FD-1 is expanded through a Joule-Thompson (JT) valve to generate refrigeration and then is fed to the wash column C1. Optionally, column C1 can be replaced by a simple flash drum, with penalty on ethane/propane recovery. A crude LPG stream is collected at the bottom of the column, and a methane rich vapor is

obtained at the top. The methane rich vapor is, after recovering refrigeration in BAHX1, sent to compression and then to fuel. The vapor from FD1 is further cooled in a second heat exchanger (BAHX2) before being fed to flash drum FD2, where it produces a hydrogen rich vapor and a methane rich liquid. The liquid is expanded in a JT valve to generate refrigeration, and then is sent back to BAHX2 to provide cooling. The resulting vapor is sent to column C1, and then processed as described above. The hydrogen rich gas is then sent to a PSA for further purification. The PSA tail gas is compressed and returned to fuel together with the methane rich gas from BAHX1.

2.2.2 HLRU Refinery Application

In a large refinery approximately 45 MMSCFD of a hydrogen rich gas containing 50% hydrogen was available for hydrogen recovery, and was currently sent to fuel. The refinery needed additional hydrogen for its hydroprocessing units, and had a “fuel long” situation. A partial condensation process was proposed for the recovery of hydrogen and LPG, followed by hydrogen purification via PSA. A block flow diagram for the process is presented in Figure 6. HLRU (Hydrogen and Liquids Recovery Unit) shown in this figure has a configuration similar

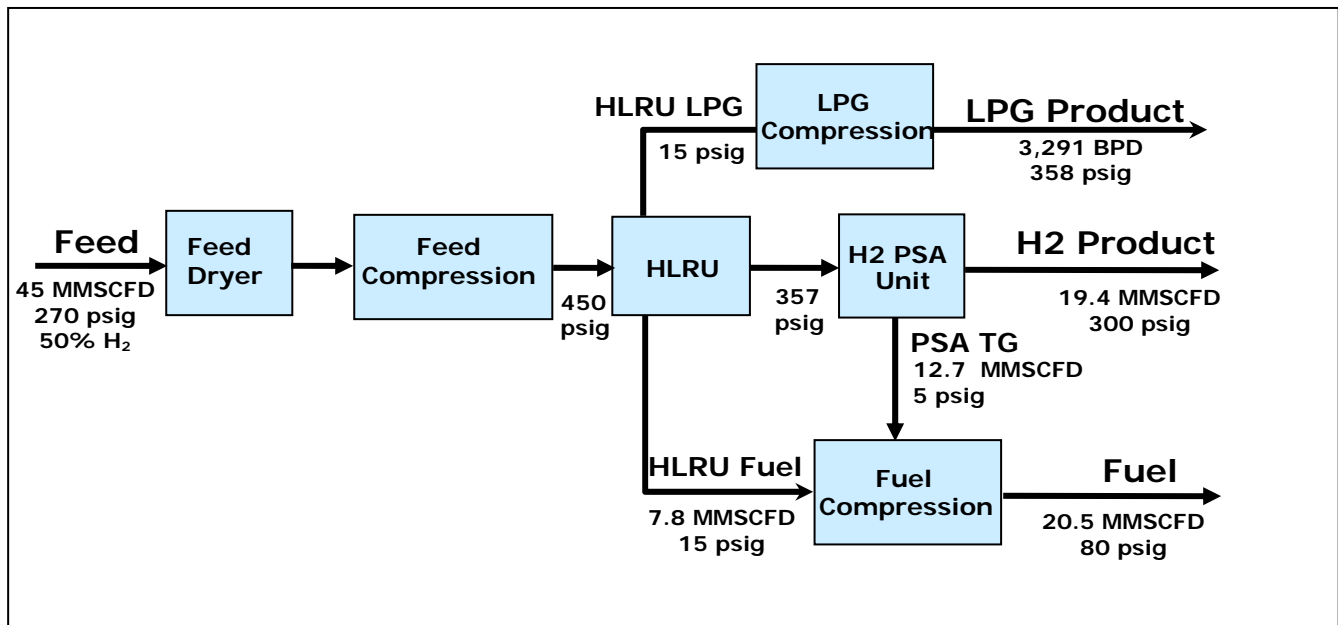


Figure 6: Block Flow Diagram for a H₂ and LPG Recovery Process

to the process in Figure 5. The refinery gas was available at 270 psig and Praxair installed additional compression to boost to the required process pressure of 450 psig. Two products were obtained as detailed in Table 2 below: 19.4 MMSCFD of a 99.99% hydrogen stream and 3,291 barrel/day of 'crude' LPG (as liquid). Given the type of process involved the main utility requirement is power for feed and products compression. Approximately 3.3 MW of power is required in total. Using an integrated cryogenic/PSA system has a direct economic benefit by upgrading the refinery fuel gas to higher value products (H₂ and crude LPG). In the example above, if we assume that the HLRU feed and the fuel gas return have natural gas value, the net uplift from using the HLRU to recover hydrogen and crude LPG is about 125% of fuel value. In addition to the advantages mentioned above, several other refinery benefits can be easily identified:

- Avoid SMR capacity increase, if incremental hydrogen is needed
- Back down SMR production, if no additional hydrogen is needed, thus reducing NG consumption
- De-bottleneck the Gas Plant by reducing overall gas volume (especially hydrogen and methane), allowing for additional LPG capacity

- Reduce CO₂ emissions – recovery of 1 MMSCFD H₂ will avoid the generation of 22.8 Metric Tons CO₂ from on-purpose H₂ production (no fuel replacement)

2.3 Refinery Gas Processor

Existing SMR integration technologies typically require refinery streams with high hydrogen and low olefin content [1] but the majority of refinery gas available does not meet these criteria. Refinery gas composition is very different than natural gas, as shown in

Table 1. Praxair has developed a new technology to address the limitations of typical refinery gas streams for hydrogen production and to permit their use in SMRs and Gas.

2.3.1 RFG constraints as SMR feed

Existing technology for treating refinery gas is based on natural gas pretreatment and is not capable of reliably treating high olefin streams at a reasonable cost. Refinery gas used as feed to SMRs is preferably high in hydrogen, which can be routed to the PSA or low in olefins to facilitate treatment with conventional natural gas pretreatment technologies using a CoMo or NiMo catalyst. Much more readily available is refinery gas from a common refinery fuel header which is the outlet for by product streams from various refinery operations. As such it typically has high olefin content, high content of C₂+ hydrocarbons and high compositional variability. High olefins present significant problems

for conventional hydrotreater, which operates within a narrow temperature window from about 550 to 750 °F. Olefin hydrogenation reactions are exothermic and each percent of olefins in the feed results in about 40-50 °F temperature rise in the hydrotreater. A refinery stream must contain less than 5% olefins to be fed to a conventional hydrotreater. Higher olefin concentrations can lead to temperatures that can cause catalyst deactivation and compromise the reliability of the SMR. In order to control the exotherm and avoid catalyst deactivation the refinery stream must be diluted either by the addition of natural gas or some of the treated gas from the hydrotreater must be cooled and recycled to the feed. The former reduces the amount of refinery gas that can be fed to SMR and the latter necessitates the use of a high temperature blower or booster compressor. Recycle compressors have been used but they introduce reliability concerns and increase capital and maintenance costs. Since compositional variations are very common with refinery gas streams, it is difficult to design and operate a hydrotreater with recycle to account for all possible variations. If off-spec refinery gas stream is detected the hydrogen plant must discontinue the use of the refinery gas to protect the SMR.

Table 1: Typical Natural Gas and Refinery Gas Compositions

Name	Refinery Gas	Natural Gas
	Mol %	Mol %
Hydrogen	28.00	-
Methane	28.00	95.00
C2+ parafins	24.00	3.50
Olefins	10.00	0.00
Nitrogen	3.50	1.00
Carbon Dioxide	3.00	0.50
Carbon Monoxide	3.50	0.00
Total	100.00	100.00
Sulfur ppm	25-250	5

Refinery gas may also contain C₂+ hydrocarbons (e.g. ethane, propane) in amounts that far exceed what is contained in natural gas. To accept these streams in a SMR a prereformer or specialized catalyst loading may have to be used, increasing the cost of the plant. In new construction an alkaliized reforming catalyst can be used but that may not be an option for existing SMRs. Alternatively the steam to carbon ratio can be increased to a higher value which depends on the C₂+ hydrocarbon content; however, this will reduce the thermal efficiency of the plant. Refinery gas composition variability must be taken into account in the plant design to prevent situations that

compromise the reliability of the SMR, such as operating with steam to carbon ratios that are either too low (catalyst coking) or too high (energy loss). Variable composition can lead to swings in SMR's operating temperature. A highly responsive analysis technique such as a mass spectrometer or calorimeter would be required for predictive control. Although with advances in controls and analytical techniques these issues can be addressed with proper design it is still desirable to have a technology that can eliminate or reduce the severity of these problems.

2.3.2 RGP Technology

The refinery gas processor is a patented [2, 3] Praxair technology based on a novel short contact time catalyst capable of operating at a space velocity of at least 50,000 hr⁻¹. This catalyst has an extended temperature window of operation (300-1600 °F) which permits operation with levels of olefins previously unachievable without feed dilution. The catalyst is in monolith form and can be on a metallic or ceramic support. A precious metal like rhodium or platinum is deposited on the monolithic support.

RGP can operate in two modes to address the difficulties in treating refinery gas. Firstly in hydrogenation mode (no oxygen) the reactor converts olefins to paraffins with the contained or supplemental hydrogen but with a much wider operating temperature window compared with conventional technology. The RGP permits utilization of refinery gas streams with high olefin content and high olefin variability. Secondly with the addition of small amounts of oxygen (up to 10% of RGP feed) and steam (up to 1:1 steam to carbon ratio) the reactor can operate in a prereforming mode that reduces the amount of hydrocarbons with two or more carbon atoms in addition to reducing olefin levels. By tuning the oxygen consumption, the refinery gas composition variations can be reduced thus improving the operation of the SMR. The same reactor can be used in both operational modes and no shut-down is required to transition between modes. The dual operation can expand the type of refinery gas composition that can be routed to the SMR and can replace two unit operations, a hydrotreater and a prereformer. In addition, RGP offers higher reliability due to the elimination of the recycle gas compressor and the ability to regulate refinery gas variability. The simple and flexible flowsheet makes it easier to retrofit existing SMRs to operate with refinery gas as a feed.

2.3.3 RGP Development

Extensive laboratory testing was undertaken at the Praxair's Technology Center

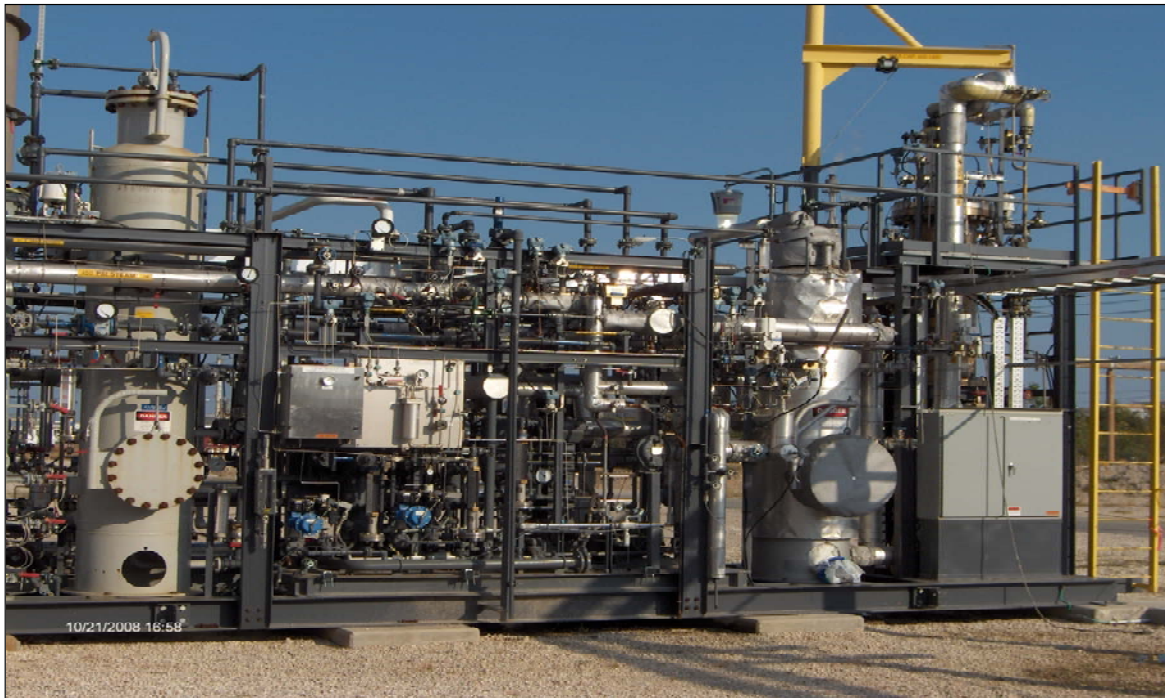


Figure 7: RGP Pilot Unit at a US Refinery

(2005-2007) with simulated refinery gas to perform parametric analysis and develop efficient operating conditions, select appropriate catalyst and test the ability to operate in hydrogenation mode or prereforming mode. Since it is not possible to simulate all of refinery gas characteristics in the laboratory a pilot test unit was designed and built at a refinery location. The design and construction was done by Praxair's engineering. The pilot unit

picture is shown in Figure 7.

The pilot unit was designed to treat 5000 scfh of refinery gas from the refinery fuel header. The pilot unit operated from 2007-2009 for more than 6000 hours and was able to demonstrate that the technology is uniquely capable of treating refinery gas. The unit operated with up to 17% olefins in the feed and up to 450 ppm organic sulfur. The unit was able to respond to feed variability,

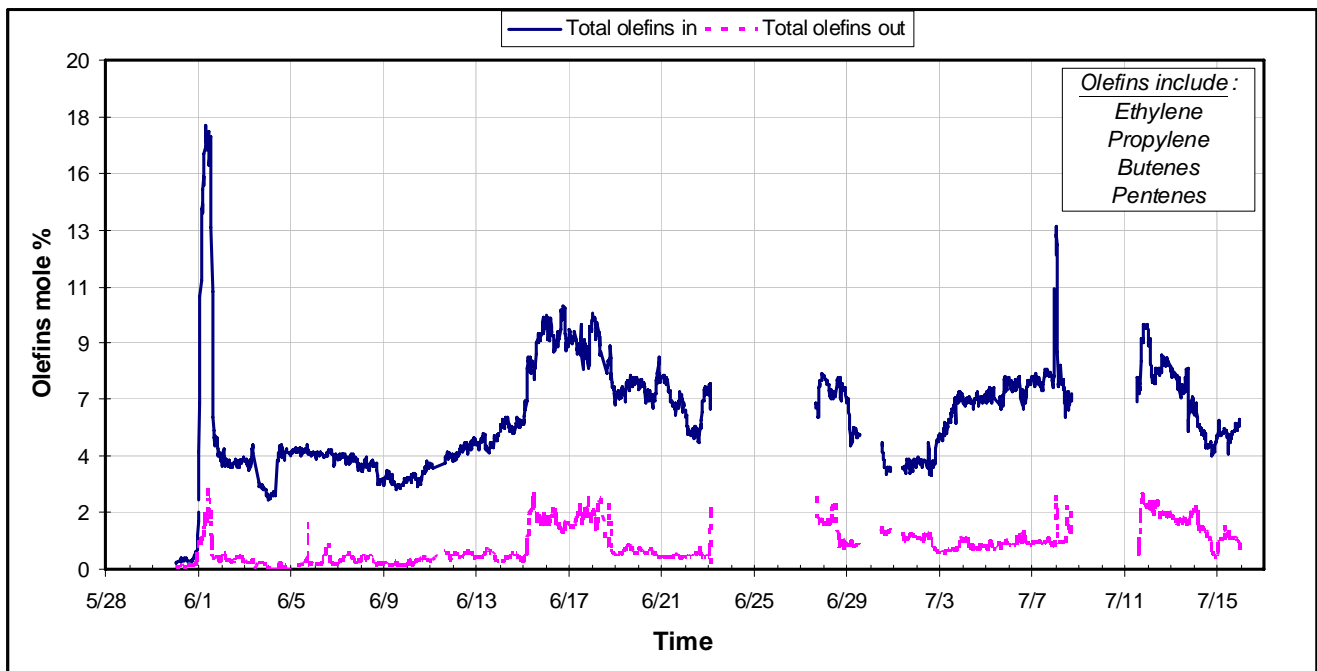


Figure 8. RGP Feed and Product Olefin Composition from Pilot Plant Experiments

demonstrated acceptable catalyst life, switched between oxidation and hydrogenation mode seamlessly, demonstrated safe operation and increased hydrogen production in prereforming mode.

Figure 8 presents the feed and product olefin composition for a period of two months with significant olefin variations in the feed (4-17%) but with product composition that remained below 1% for the majority of time. Only when the unit was operated with very high propylene in the feed did the exit olefin composition approach 2% at the high reactor exit temperature (1100 °F), where propylene conversion was limited by thermodynamic equilibrium. The level of olefins achieved at the exit of the RGP can be easily handled by the SMR hydrotreater, and allows for reliable plant operation with refinery gas feed.

The RGP currently can be cost justified in cases where olefin content is the main impediment to using a refinery gas as an SMR feed. The RGP can be designed to operate without a hydrotreater or it can be retrofitted in existing plants as a first treatment step followed by a hydrotreater for final polishing. The RGP has a capital advantage over a hydrotreater with recycle compressor and eliminates the main reliability problem associated with a recycle system.

Praxair is finalizing the parameters that allow the RGP to be used to increase hydrogen production and displace a pre-reformer. Testing has demonstrated pre-reforming activity in oxidation mode and preliminary studies indicate that an RGP system could have a substantial capital advantage when compared to a pre-reformer in a debottleneck scenario.

2.3.4 Full-Scale Implementation

Managing the fuel system is integral to running a refinery at optimal efficiency. Praxair's in house experts have analyzed several refinery systems to find technologies to meet overall energy and hydrogen demand. Praxair has evaluated several opportunities to upgrade refinery fuel gas and in all cases with problematic high olefin steams RGP was found to have an advantage over conventional alternatives. Praxair is currently in contract negotiations with a refinery interested in implementing the first full-scale RGP unit.

3 Praxair's Approach to Evaluating Refinery Opportunities

With a combination of proven and new technologies Praxair is well positioned to address refinery "fuel long" situations. If refinery gas with high hydrogen and low olefins is available then a PSA or a conventional SMR can be used as outlets.

If high olefins, variability and high hydrocarbons are concerns then RGP is available to address these issues. If hydrocarbon recovery is desired Praxair can design a cryogenic system to take advantage of available refinery streams while simultaneously producing LPG or chemical feedstock and high purity hydrogen.

Praxair is in a unique position to offer hydrogen solutions to refinery operators because it combines experience from operating hydrogen plants, engineering and building hydrogen plants, performing research and development on hydrogen production and hydrogen recovery (PSA and cryogenic), and having a dedicated team of experts specializing in refinery operations. In order to assist refinery customers in their efforts to obtain better business performance with regard to cost reduction, profit improvement and regulatory compliance, Praxair has developed the following staged approach:

- Perform an evaluation of the overall hydrogen and fuel/energy systems using in-house expert tools and models, which will assist in identifying potential value-added opportunities;
- Work closely with the refinery to fine-tune and validate the opportunities identified;
- Develop the offering, based on refinery's feedback and internal evaluation

Using this staged process Praxair taps into internal expertise existent at various levels within the organization, and makes sure that the solution offered will meet refinery needs. In addition feedback from customers is used to improve existing offerings and to develop new applications. This integrated approach is critical in achieving our targets which are increased profitability, sustainability, reduced energy footprint and reduced CO₂ emissions.

4 References

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