Natural gas has proven to be a clean burning, flexible fuel which has gained global acceptance as a preferred choice in the energy fuel mix. Supply of natural gas is expected to grow for the next 20 years given the global economic, environmental and geopolitical benefits as gas becomes a more predominant part of the energy mix. Forecasts predict that gas will increase to 25% (from 22%) of the total energy mix, becoming the only fossil fuel that is increasing on a percentage of total mix perspective. This 3% increase in mix equates to a 50% increase in absolute consumption volume. To support this demand growth, conventional and unconventional resources must be exploited. Although there will be challenges, the opportunities are great.

The unconventional gas revolution has enabled a transformation of the US energy mix. Interest in shale gas has spread to other parts of the world; however, each new gas supply brings challenges for treating, natural gas liquid (NGL) recovery, gas quality, and gas...
distribution infrastructure. This can be particularly true of shale gas, as the composition can vary significantly from one field to another. Additionally, shale gas resources can exist in remote regions challenged by limited water infrastructure, and other logistical challenges requiring innovative processing solutions. As in the US shale gas revolution, exploration and production (E&P) companies need to partner with solution providers to assure they can monetise their resources in a timely, capital efficient manner. Project success often hinges on executing gas projects quickly at reduced cost compared to traditional methods, as well as ensuring the projects can maximise the recovery of high value NGL products at low production costs and downtime.

Shale gas in the US has rapidly increased as a source of natural gas. Led by new applications of hydraulic fracturing technology and horizontal drilling, shale gas new source development has offset declines in production from conventional gas reservoirs and has led to major increases in reserves of US natural gas. Largely due to shale gas discoveries, US dry natural gas proved reserves have more than doubled from 164 000 ft³ in 1998 to 334 000 ft³ in 2011, with more than 70% of this increase due to additions after 2006. The economic success of shale gas in the US has led to development of shale gas in Canada, and more recently, has spurred interest in shale gas possibilities in China, Europe, Asia, and Australia. US shale gas continues to change the energy mix within the country and has a substantial impact on US energy self-sufficiency.

The rapid growth in shale production, especially in geographically diverse locations from traditional production, has led to the need for a rapid expansion of midstream assets. This rapid expansion required a strong partnership between operators and suppliers to focus a large portion of the US equipment production capacity on designing, installing and operating these new plants in parallel with field developments and gas production estimates.

The parallel processing of production assets and gas processing facilities made it particularly challenging to design new facilities based on gas quality information from a few initial wells. It was also challenging to be flexible while dealing with potential variations as more wells were drilled in the same area. In addition, operators often wanted to design gas processing plants before they had detailed gas compositions from pilot wells. This uncertainty in future gas quality adds to the complexity of plant design and can increase the risks associated with the profitability of overall field development.

**Gas processing options**

Unconventional gas is often contaminated with CO₂, and removal is required when the produced gas contains higher levels than the downstream pipeline will accept, which is typically 2 - 3 %. In addition, when NGL recovery is desirable, cryogenic systems will require CO₂ concentrations to be lowered to approximately 0.5 - 1%, depending on the richness of the gas and the level of NGL recovery desired. High levels of CO₂ can lead to freeze out at the normal operating temperatures below -125 °F. Y-Grade NGL specifications for cryogenic liquid production normally limits CO₂ to 0.35 LV% CO₂/°C₂ or 1000 ppmw. The right technology for acid gas removal depends on the amount of acid gas in the feed and the desired contaminant level in the product. The most common processes for removing CO₂ are amine treating, membranes and a molecular sieve.

Conventional and unconventional gas will be water saturated at the temperature pressure where the well is produced. This water vapour must be reduced to avoid corrosion and freezing in downstream processing units and pipeline distribution networks. The most prevalent solutions for pipeline gas is contacting the gas with 99% triethylene glycol (TEG) to dry the gas to below 7 lbs./000 ft³. Cryogenic NGL recovery will require deeper drying in a molecular sieve unit to dry the gas to below 100 ppmv.

NGLs contained in shale gas provide an economic incentive for recovery beyond just treating for pipeline sale. These NGLs are recovered for refinery, petrochemical or other distributed fuel uses where their value exceeds what is recoverable on a strictly British thermal units (Btu) basis than if the NGLs are left in the natural gas stream. Local market conditions can vary significantly with regard to ethane and liquid petroleum gas (LPG) values. In many new shale gasfields, there can be significant local price dislocations due to lack of takeaway capacity for specific products. This requires a flexible cryogenic plant design if the operator wants to react to local market conditions and maximise profitability from shale production.

**The modular plant solution**

The ‘fast gas’ rapid NGL recovery model has enabled the shale gas revolution by aligning supplier capabilities and operators’ needs for rapid and economical development of new shale production. The rapid increase in dry shale gas production placed downward pricing pressure on natural gas to the point that dry natural gas was ‘borderline’ economical for operators. At this point, attention shifted to ‘wet gas’, or shale gas that contained significant volumes of NGLs that command a market price tied to crude oil that is higher than natural gas prices. The traditional plant delivery model, which takes two or more years to implement, created a costly delay. This formed a barrier to develop these vital resources.

Just as George Mitchell developed hydraulic fracturing, an entrepreneur emerged with a solution. This entrepreneur was Tom Russell. He developed a model of providing preengineered, factory built modular plants that enabled the
delivery and installation of NGL recovery plants at least six months faster than the stick built alternatives. In addition, the Russell approach did not require the operator to know exactly how rich his gas stream was upfront. Plant fabrication could occur in parallel to drilling, fracturing and well testing. For operators developing new resources, these new capabilities to parallel the field and plant development processes were critical to bringing on new assets quickly. They also provided a rapid return on the large capital outlays required to meet growing shale development.

Speed is of the essence in the midstream business model, and the typical stick built project timeline can run 24 months from placing the order to seeing plant startup. In part, this is because a sequential process is required, from a completed gas analysis to the design of equipment starts in front end engineering and design (FEED). After design is completed in FEED, procurement can order long lead equipment. FEED and procurement are sequential steps in the stick built project. However, modular plants provide a faster alternative by integrating FEED and procurement activities to optimise overall project schedule and profitability. Some equipment is pre-engineered to start procurement from day one, even before gas analysis is necessarily available. Once gas analysis is known, important value added equipment is optimised for the project. Efficient value added optimisation allows FEED and procurement to be integrated in a single, seamless process. These modular plant project innovations enable starting a plant’s ‘first gas’ up to six months sooner than with stick built solutions.

The skid mounted equipment can provide greater mobility in challenging locations. Remote locations with limited resources, restricted access and other difficulties are more easily overcome. Ideal candidates for modularisation are packaged units sized for up to 300 000 ft³/d of volume, with even larger plants accommodated by multiple trains. These systems are integrated in a shop setting before being shipped to the plant site. This provides assurance that equipment will assemble quickly, fit up properly at the field site, and ensure a smooth and rapid installation, commissioning and startup.

Placing the plant on stream faster and recovering NGLs sooner is quite valuable. A typical example of a 200 000 ft³/d plant with a moderate NGL content (3 gal./min) will generate more than US$ 10 million of additional value each month in recovering the NGLs at current prices as opposed to leaving them in the gas and receiving heating value. Earlier delivery by six months could potentially be worth more than US$ 60 million, which can be 50% of the total installed cost of the full plant. Rapid NGL recovery is vital in improving the overall process economics of the shale gas and liquid hydrocarbon value stream.

Modularised plants in action

Some of the real life applications seen across the US shale basins in the last few years showcase the unique challenges customers face. For example, flat topography in the Eagle Ford might be replaced by more mountainous terrain in the Marcellus. High altitude areas such as the San Juan Basin can be contrasted with lower lying areas in Louisiana. Some areas produce lean gas with low to moderate levels of NGL, and some areas have high levels of NGL that demand more recovery with associated equipment.

Case study one

In the Marcellus Shale Basin, an operator acquired a 120 000 ft³/d cryogenic unit with a refrigeration package to process natural gas containing 6 - 7 gal./min. After startup, the customer determined that they had higher gas rates than anticipated. The equipment supplier worked with the customer to find a solution, designing a flexible system that would meet their gas specifications. The customer was then able to push gas volume throughput to 115% of design and process 138 000 ft³/d. This enabled the client to secure more gas contracts.

Since the installation of the first plant, the site has increased from 138 000 ft³/d capacity to 660 000 ft³/d by adding two, 200 000 ft³/d cryogenic units with refrigeration and a 120 000 ft³/d cryogenic unit with refrigeration. Because of this, the customer was able to break ground in a green field site and then expand into a major gas processing hub for the Marcellus area. The customer has returned to modular solutions for additional gas processing needs.

Case study two

In the Eagle Ford Shale, an operator was aware that he had to process up to 600 000 ft³/d of gas within a two year timeframe. The operator partnered with the equipment supplier to make certain that they could achieve this without consuming the time it would take to construct a stick built plant. Adopting a modular approach saved time in project timeline execution and made rapid NGL extraction a reality.

The first 200 000 ft³/d cryogenic plant installation was finalised in the third quarter of 2012. The second 200 000 ft³/d cryogenic installation was finalised in the first quarter of 2013, and the final cryogenic 200 000 ft³/d installation will be finalised in the first quarter of 2014. One benefit of this schedule was that equipment was installed as gas demand ramped up, which only a modular approach can do. Another benefit was that the operator had three identical plants with the same list of common spare parts. This signifies a greater maintenance familiarity as more plants came on line. The operator could then purchase common compression for each train, leading to a more homogenous operation.

Conclusion

When delivered by an experienced solution provider, solutions for CO2 removal, dewpointing and NGL recovery can be delivered as prefabricated, skid mounted modules that provide feed composition flexibility and rapid NGL recovery. This lowers fabrication costs, speeds installation and provides high onstream efficiency. Modular, prefabricated solutions enable economic development of shale gas resources that would otherwise pose as daunting processing challenges given their inherent variability in gas composition. Operators using this modular approach truly benefit through more efficient operations and optimal monetisation.