Increasing Natural Gas Value Chain Complexity

Capability to Manage all Major Gas Processing Needs
Distributed Global Gas Reserves

Remaining recoverable natural gas resources
tm cubic meters (tcm), 2011

Sources: IEA, BP, PFC Energy, EIA

Gas Composition Varies, Continue to Develop Techno Economic Solutions

No circle within a region indicates minimal known Acid Gas or NGL Content

Sources: IEA, BP, PFC Energy, EIA
Gas Treating Requirements

Treating Technologies are Selected Based on Feed Composition and Product Specs

Gas Composition:
- \( \text{CH}_4 \), \( \text{C}_2+ \), \( \text{H}_2\text{O} \), \( \text{H}_2\text{S} \), \( \text{CO}_2 \), \( \text{N}_2 \), \( \text{Hg} \)

Pipeline Gas:
- Pipeline Spec:
  - \( \text{CO}_2 < 2\text{-}8\% \text{ ppm} \)
  - \( \text{H}_2\text{S} < 4 \text{ ppm} \)
  - \( \text{Hg} < 0.01 \mu\text{g/Nm}^3 \)
  - \( \text{H}_2\text{O} < 100 \text{ ppm} \)

LNG Spec:
- \( \text{CO}_2 < 50 \text{ ppm} \)
- \( \text{H}_2\text{S} < 2\text{-}4 \text{ ppm} \)
- \( \text{Hg} < 0.01 \mu\text{g/Nm}^3 \)
- \( \text{H}_2\text{O} < 0.1 \text{ ppmv} \)
### Lessons from U.S Shale Gas Variability

<table>
<thead>
<tr>
<th></th>
<th>Barnett Shale Gas Composition</th>
<th>Marcellus Shale Gas Composition</th>
<th>New Albany Shale Gas Composition</th>
<th>Antrim Shale Gas Composition</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Well</strong></td>
<td>1  2  3  4</td>
<td>1  2  3  4</td>
<td>1  2  3  4</td>
<td>1  2  3  4</td>
</tr>
<tr>
<td><strong>C&lt;sub&gt;1&lt;/sub&gt;</strong></td>
<td>80.3 81.2 91.8 93.7</td>
<td>79.4 82.1 83.8 95.5</td>
<td>87.7 88.0 91.0 92.8</td>
<td>27.5 57.3 77.5 85.6</td>
</tr>
<tr>
<td><strong>C&lt;sub&gt;2&lt;/sub&gt;</strong></td>
<td>8.1 11.8 4.4 2.6</td>
<td>16.1 14.0 12.0 3.0</td>
<td>1.7 0.8 1.0 1.0</td>
<td>3.5 4.9 4.0 4.3</td>
</tr>
<tr>
<td><strong>C&lt;sub&gt;3&lt;/sub&gt;</strong></td>
<td>2.3 5.2 0.4 0.0</td>
<td>4.0 3.5 3.0 1.0</td>
<td>2.5 0.8 0.6 0.6</td>
<td>1.0 1.9 0.9 0.4</td>
</tr>
<tr>
<td><strong>CO&lt;sub&gt;2&lt;/sub&gt;</strong></td>
<td>1.4 0.3 2.3 2.7</td>
<td>0.1 0.1 0.9 0.3</td>
<td>8.1 10.4 7.4 5.6</td>
<td>3.0 0.0 3.3 9.0</td>
</tr>
<tr>
<td><strong>N&lt;sub&gt;2&lt;/sub&gt;</strong></td>
<td>7.9 1.5 1.1 1.0</td>
<td>0.4 0.3 0.3 0.2</td>
<td>65.0 35.9 14.3 0.7</td>
<td></td>
</tr>
</tbody>
</table>

- **C<sub>2</sub>: 11.8 – 2.6**
- **C<sub>3</sub>: 5.2 – 0.0**
- **CO<sub>2</sub>: 0.3 – 2.7**
- **N<sub>2</sub>: 1.0 – 7.9**
- **C<sub>2</sub>: 16.1 – 3.0**
- **CO<sub>2</sub>: 0.1 – 0.9**
- **C<sub>3</sub>: 2.5 – 0.8**
- **C<sub>1</sub>: 85.6 – 27.5**
- **N<sub>2</sub>: 0.7 – 65.0**

Component Variations Impact Interchangeability with Other Gas Supplies
## Typical FLNG Feed Properties

<table>
<thead>
<tr>
<th>LNG Specifications</th>
<th>Typical Feed Properties in key areas</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td><strong>South America</strong></td>
</tr>
<tr>
<td><strong>H₂S, ppmv</strong></td>
<td>&lt; 2 - 4</td>
</tr>
<tr>
<td><strong>Total Sulfur, ppmv</strong></td>
<td>&lt; 10 - 50</td>
</tr>
<tr>
<td><strong>CO₂, %</strong></td>
<td>&lt; 50 ppmv</td>
</tr>
<tr>
<td><strong>Hg, μg/Nm³</strong></td>
<td>&lt; 0.01</td>
</tr>
<tr>
<td><strong>H₂O, ppmv</strong></td>
<td>&lt; 0.1</td>
</tr>
</tbody>
</table>

**Tight Requirements Often Necessitate Sophisticated Pretreatment Solutions**
Gas Plant Development: Decision Criteria

**Upstream Factors**
- Methane
- Ethane
- Propane
- Butanes
- C₅⁺ condensate
- Oil

**Acid Gases:** CO₂, H₂S, Mercaptan, COS
**Other:** Mercury, Arsenic, Nitrogen, Water

**Midstream Factors**
- HC Distribution
- Production Profile
- Contaminants
- Pressure, Flow
- Ambient Conditions
- Offshore/Onshore
- Fiscal Regime
- Environmental Constraints

**Plant Configuration & Design Decisions: Gas Processing Functional Blocks**
- Compression
- Acid Gas Removal
- Sour Gas Removal
- Hydrocarbon Management
- Dehydration
- Other Contaminant Removal
- Utilities & Disposal

**Downstream Factors**
- By-Products
- Products
- Opp. Efficiency
- Consumption
- Disposal

**By-Products**
- Sales gas / LNG
- NGL’s
- Spec products
- C₅⁺ condensate

**Products**
- Availability
- Flexibility

**Opp. Efficiency**
- Energy
- Chemicals
- Labor

**Consumption**
- Air
- Water
- Subsurface
Requires a Diverse Portfolio of Treating Technologies
Membrane Systems

Membranes are:

- Membranes are thin, semi-permeable barriers that selectively separate certain components
- Characterized by permeability or capacity (flux) and selectivity

Membrane Process

Hydrocarbons, N₂

- Fast
- Slow

CO₂, H₂S, H₂O

Membrane Advancement Dives Higher Capacity and Higher Selectivity
Membrane vs Amine: Shale Gas Comparative Study

Case Example
- Total Installed Savings = $12MM
- OPEX Savings = 1.5 MM / yr
- NPV advantage ~$28 MM

NPV Separax over NPV Amine
NPV = Total install lost + 10x OPEX

Factors
- Remote Location
- Site Erection Logistics
- Clean water availability
- Solvent Transportation & Disposal
- Environmental Impact
- Acid Gas Destruction
- Hydrocarbon Values

Significant Value for Membrane Over Amines; Project Dependent
**Actual recovery dependent on feed gas composition, pressures, flow rates**

A Broad Portfolio to Fit your HC Recovery or Removal Requirement
Gas Treating Summary

1) Select the proper technology within each separate gas processing block

2) Account for interactions across the different processing blocks

3) Adjust sequence of processing blocks for overall system optimization
Integrated Gas Pretreating Complex
RasGas LNG Expansion Phase 1 / RGX

UOP SELEXOL™ Process
UOP Amine Guard™ FS Process
UOP Natural Gas MOLSIV™ Process

Picture by courtesy of RASGAS
Modular Fabrication Solutions
Key Technology Innovations

Hydraulic fracturing

Seismic Imaging

Horizontal Drilling

“Fast gas” NGL Recovery
## What We Mean with Modular Design

### Modular Solution

“The overall process of design, component and/or process leverage, enabled by a common pre-engineered design architecture where the modules are standard except where customization is required”

### Key definitions within Modular Solution

- **Pre-engineered**: Thoughtful initial design allowing for ultimate re-use
- **Modularization**: Discrete modules which can be aggregated into a single solution where only interfaces are prescribed, including inputs and outputs but not the block complete block design
- **Standardization**: General term used to cover the extent of module reuse
- **Industrialization**: Adoption of industry standards with no / minimal additional company specifications / requirements
- **Modular pre-fabrication**: Shop fabrication of modules

**SOURCE**: Team analysis
Modular Solutions Increase Overall Lifetime Value

SOURCE: Based on UOP estimation and various oil and gas industry examples
Cryogenic Plant Skids

Skids are Factory Built and Ready for Installation Saving up to 20-30% per Project
Field Design Support Package
Standard Cryo Plant

- 2 to 4 GPM C2+
- Unsaturated Feed
- "Low" CO₂ in Feed

Inlet Gas ➔ MOLSIV™ ➔ Cryo Plant ➔ Residue Gas ➔ Y-grade
Standard Cryo + Mechanical Refrigeration (MR)

- Inlet Gas (saturated feed) → MOLSIV™ (saturated feed) → Cryo Plant → Y-grade
- Refrig Loop → Residue Gas

**6 GPM C2+**
- Unsaturated Feed
- “Low” CO₂ in Feed
Standard Cryo + MR + Rich Gas Conditioner

- Inlet Gas
- RGC
- MOLSIV™ (saturated feed)
- Cryo Plant
- Refrig Loop
- Residue Gas
- Stabilizer

10 GPM C2+
- Unsaturated Feed
- “Low” CO₂ in Feed
Utilities, site engineering, field fabrication and construction works

Facilities design, engineering and fabrication. Ancillary equipment balance of fabrication

Ancillary equipment design and engineering and some fabrication

Core Modular Process Plants
Rapid NGL Recovery Improves Return on Investment

- Typical example of revenue associated with NGL recovery
- 200 MMSCFD of 3 GPM gas (~1,100 BTU/SCF)
- Pre-engineered modular design can provide 20% schedule advantage vs. custom field erected

<table>
<thead>
<tr>
<th></th>
<th>Barrel Comp</th>
<th>Price Basis</th>
<th>Value over fuel $M/month</th>
</tr>
</thead>
<tbody>
<tr>
<td>Methane</td>
<td>Fuel Value</td>
<td>$0.0</td>
<td></td>
</tr>
<tr>
<td>Ethane</td>
<td>67% Fuel Value</td>
<td>$0.0</td>
<td></td>
</tr>
<tr>
<td>Propane</td>
<td>15% 73% of crude</td>
<td>$2.7</td>
<td></td>
</tr>
<tr>
<td>n-Butane</td>
<td>4% 83% of crude</td>
<td>$0.8</td>
<td></td>
</tr>
<tr>
<td>i-Butane</td>
<td>5% 81% of crude</td>
<td>$1.0</td>
<td></td>
</tr>
<tr>
<td>Natural Gasoline</td>
<td>9% 74% of crude</td>
<td>$1.3</td>
<td></td>
</tr>
</tbody>
</table>

1. Typical wellhead price $9/mmbtu (51% of crude)
2. Assuming crude price of $105/bbl

Amount Generated Monthly

$5.8MM

Modular Plants – Faster Delivery, Enhanced Value
Increased Gas Processing Capacity for Enhanced LPG Supply

China LPG Opportunity

- LPG Production (+3.7% CAGR) & consumption (+4.3% CAGR) growth
- Growing net import deficit
  - Deficit increases on average 0.5 MTA per year
  - Deficit growing at 7% CAGR
  - Grows from 4 MTA in 2015 to 12 MTA in 2030
- Displacement of imports enabled by increased economic LPG recovery via gas processing plants
In Closing…

A Complex Natural Gas Value Chain

+  

Varying Natural Gas Reserve Compositions and Geographies

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Diverse Gas Treating needs that Require Fit for Purpose Technology and Delivery Models
UOP Company Profile
Serving the Gas Processing, Refining & Petrochemical Industries

Profile — Significant Technology Position

Business Units:
- Gas Processing and Hydrogen (GP&H)
- Process Technology & Equipment (PT&E)
- Catalysts, Adsorbents & Specialties (CA&S)
- Renewable Energy and Chemicals (RE&C)

Offering:
- Technology, catalyst & services to the refining, petrochemical and gas processing industries
- Supplier of molecular sieve adsorbents to process and manufacturing industries

UOP Facilities — Global Footprint

Worldwide Headquarters
Des Plaines, Illinois (suburban Chicago)
3,500+ Employees

- 20 Offices
- 17 Countries
- 12 Manufacturing Facilities
- 5 Engineering Centers

UOP Offices
UOP Manufacturing Sites

Sales: Breakdown

- Equipment 35%
- Products 19%
- Services 13%
- Licensing 7%

Sales: Geographic

- North America 32%
- Asia Pacific 19%
- China 12%
- South America 9%
- Middle East 9%
- E&A 9%
- CIS 5%
- India 5%