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Gas Processing: A Global Perspective

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UOP, A Honeywell Company

1914 - 2014 | A Century of Innovation

Increasing Natural Gas Value Chain Complexity

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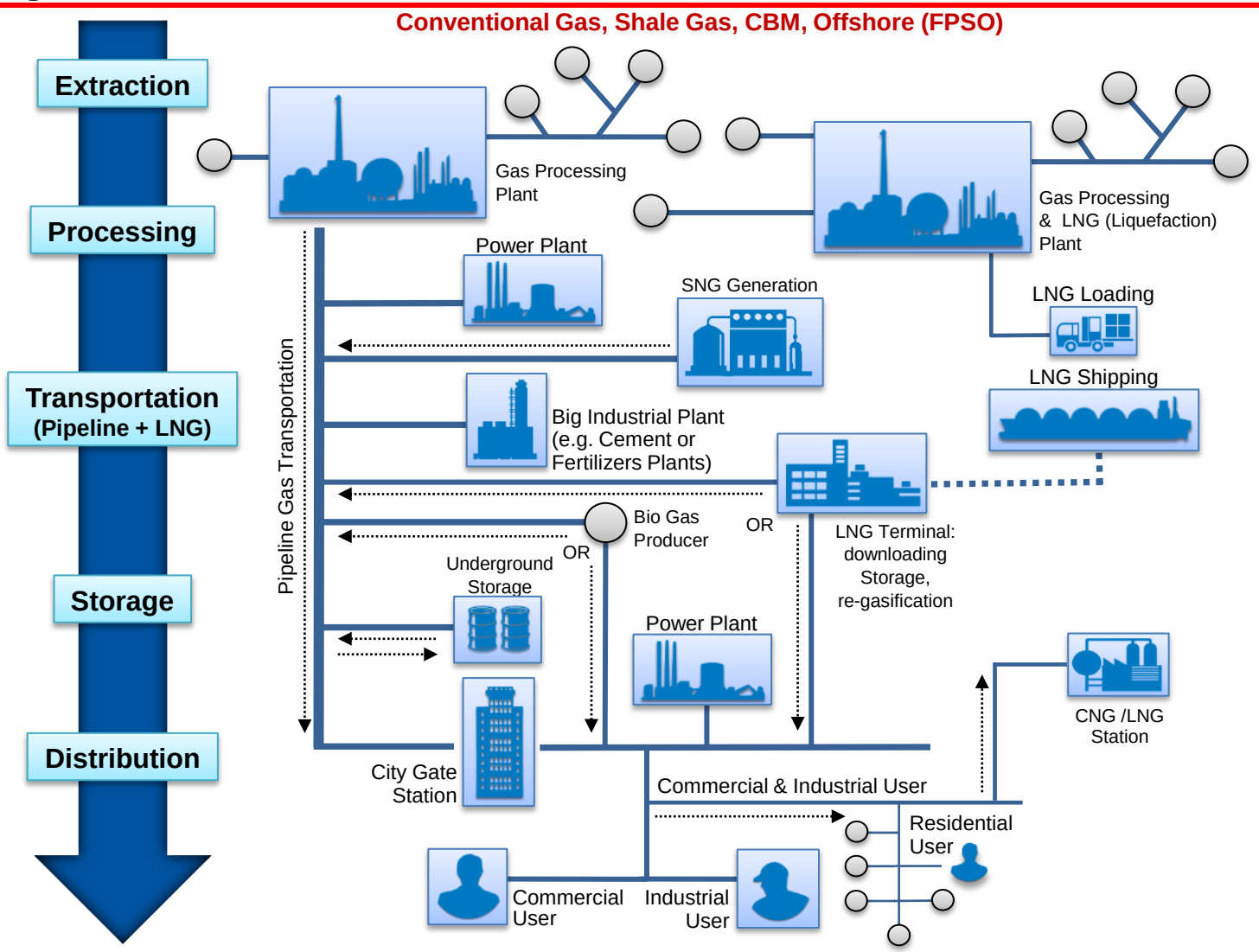

Capability to Manage all Major Gas Processing Needs

Distributed Global Gas Reserves

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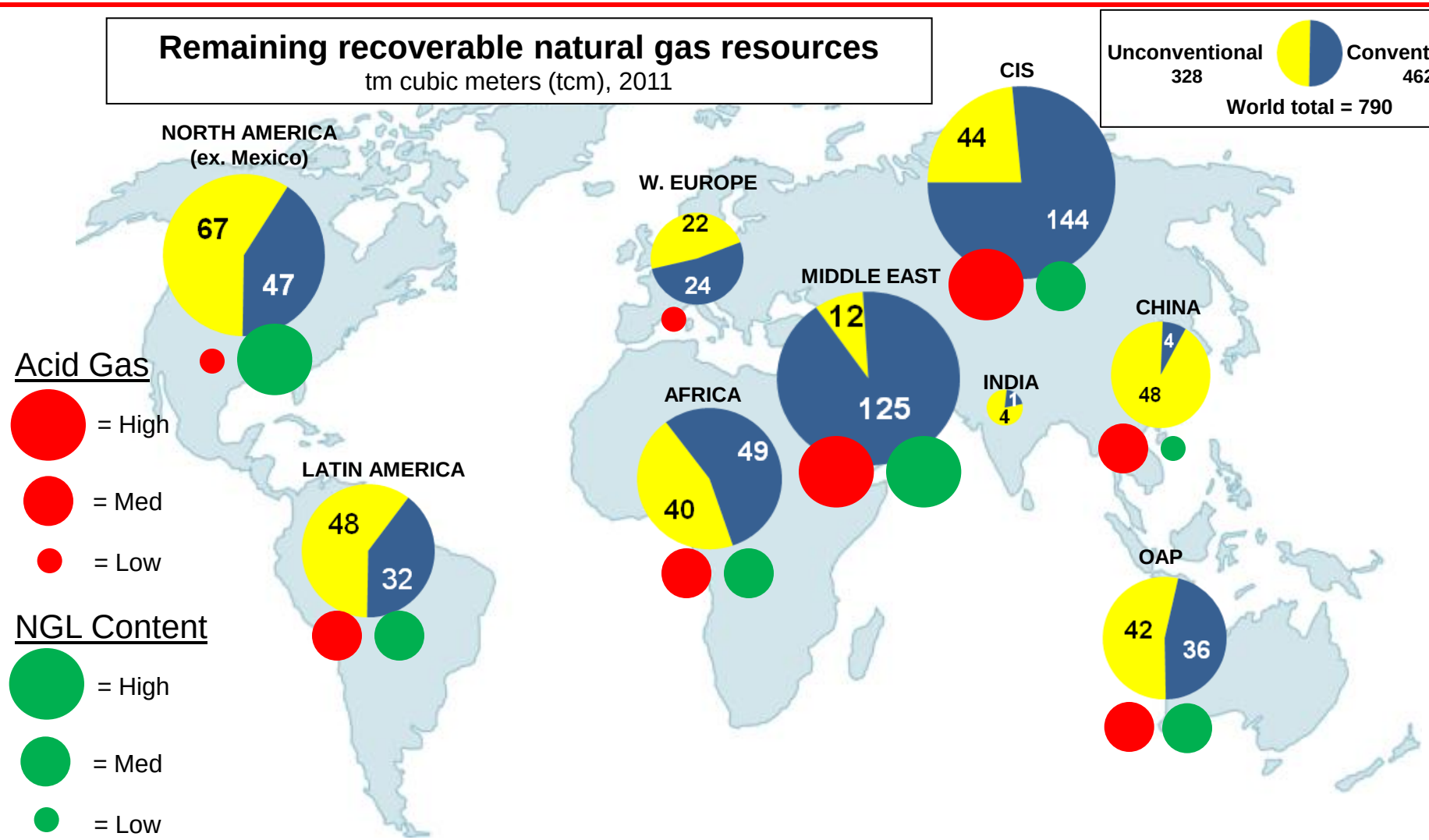
Remaining recoverable natural gas resources
tm cubic meters (tcm), 2011

Unconventional 328 | Conventional 462
World total = 790

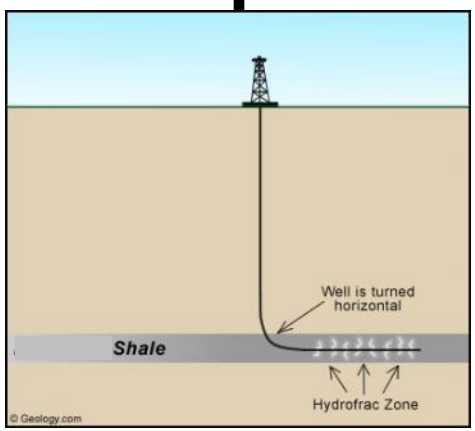


No circle within a region indicates minimal known Acid Gas or NGL Content

Sources: IEA, BP, PFC Energy, EIA

Gas Composition Varies, Continue to Develop Techno Economic Solutions

Gas Treating Requirements



Gas Composition

CH_4, C_2+, H_2O, H_2S, CO_2, N_2, Hg

Acid gas CO_2 H_2S | H_2O | N_2 | Hg | C_2+

Pipeline Gas

Pipeline Spec:

- CO_2 < 2- 8% ppm
- H_2S < 4 ppm
- Hg < 0.01 µg/Nm^3
- H_2O < 100 ppm

LNG

LNG Spec:

- CO_2 < 50 ppm
- H_2S < 2 - 4 ppm
- Hg < 0.01 µg/Nm^3
- H_2O < 0.1 ppmv

Treating Technologies are Selected Based on Feed Composition and Product Specs

Lessons from U.S Shale Gas Variability

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	Barnett Shale Gas Composition				Marcellus Shale Gas Composition				New Albany Shale Gas Composition				Antrim Shale Gas Composition				◇
Well	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**	
C_1	80.3	81.2	91.8	93.7	79.4	82.1	83.8	95.5	87.7	88.0	91.0	92.8	27.5	57.3	77.5	85.6	• 95.5 – 27.5
C_2	8.1	11.8	4.4	2.6	16.1	14.0	12.0	3.0	1.7	0.8	1.0	1.0	3.5	4.9	4.0	4.3	• 16.1 – 0.8
C_3	2.3	5.2	0.4	0.0	4.0	3.5	3.0	1.0	2.5	0.8	0.6	0.6	1.0	1.9	0.9	0.4	• 5.2 – 0.0
CO_2	1.4	0.3	2.3	2.7	0.1	0.1	0.9	0.3	8.1	10.4	7.4	5.6	3.0	0.0	3.3	9.0	• 0.0 – 10.4
N_2	7.9	1.5	1.1	1.0	0.4	0.3	0.3	0.2					65.0	35.9	14.3	0.7	• 0.2 – 65.0
○	• C2: 11.8 – 2.6 • C3: 5.2 – 0.0 • CO2: 0.3 – 2.7 • N2: 1.0 – 7.9				• C2: 16.1 – 3.0 • CO2: 0.1 – 0.9				• C3: 2.5 – 0.8				• C1: 85.6 – 27.5 • N2: 0.7 – 65.0				

Component Variations Impact Interchangeability with Other Gas Supplies

Typical FLNG Feed Properties

	LNG Specifications	Typical Feed Properties in key areas		
		South America	South East Asia	Australia
H_2S, ppmv	< 2 - 4	5 - 1000	5 - 200	2 - 50
Total Sulfur, ppmv	< 10 - 50	5 - 1000	5 - 250	2 - 60
CO_2, %	< 50 ppmv	2 - 55	9 - 50	2 - 30
Hg, µg/Nm³	< 0.01	0 - 100	200 - 2000	50 - 200
H_2O, ppmv	< 0.1	Saturated	Saturated	Saturated

Tight Requirements Often Necessitate Sophisticated Pretreatment Solutions

Gas Plant Development: Decision Criteria

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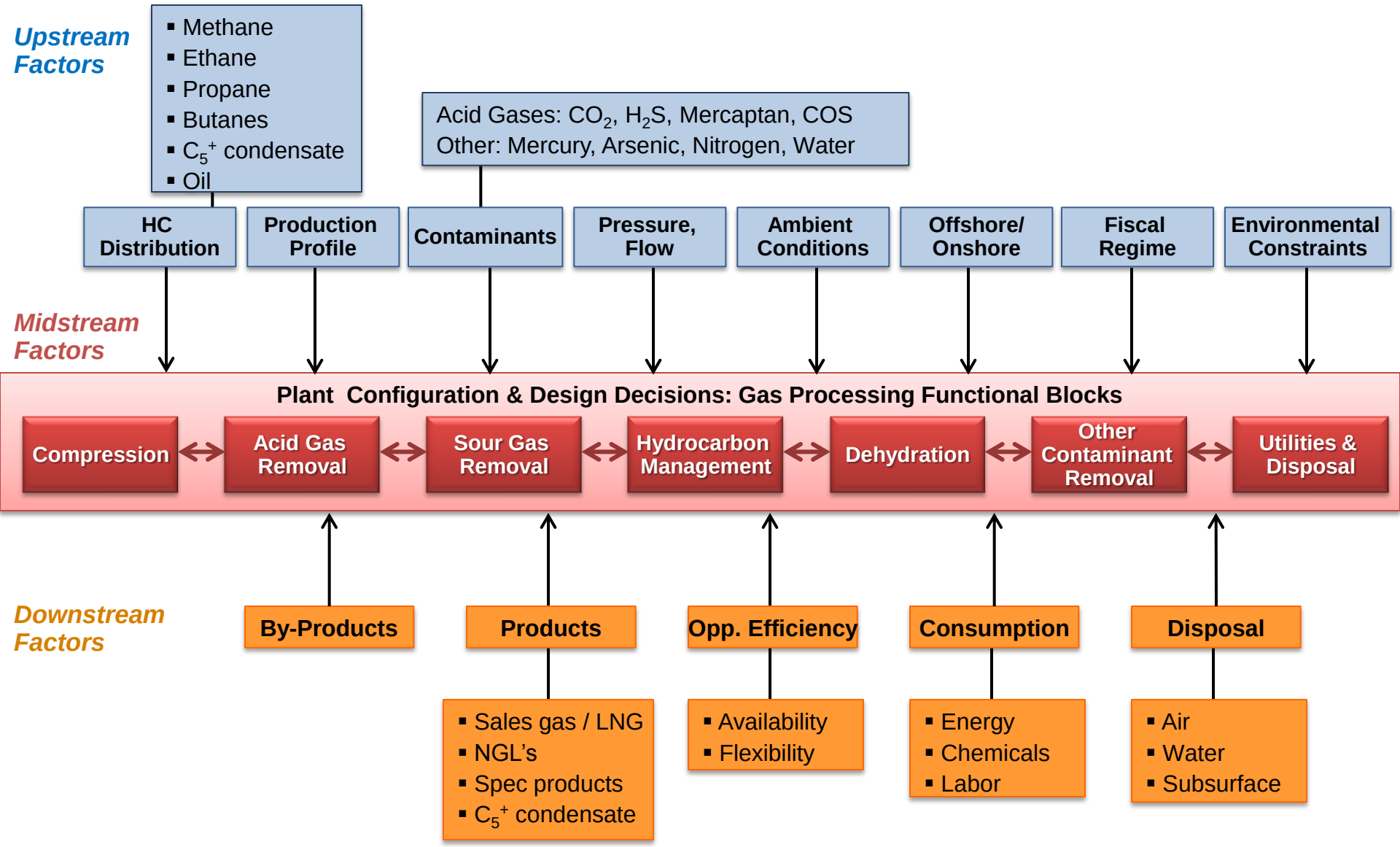
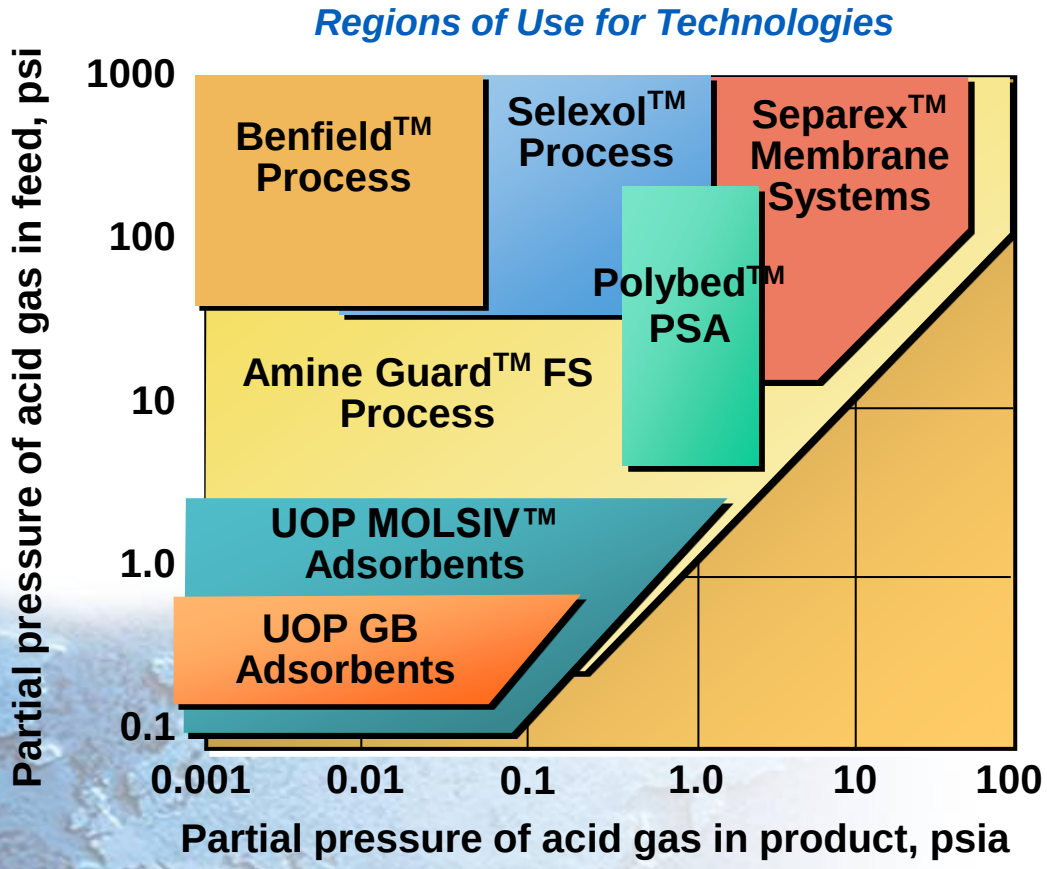


Acid Gas Removal…



Requires a Diverse Portfolio of Treating Technologies

Membrane Systems

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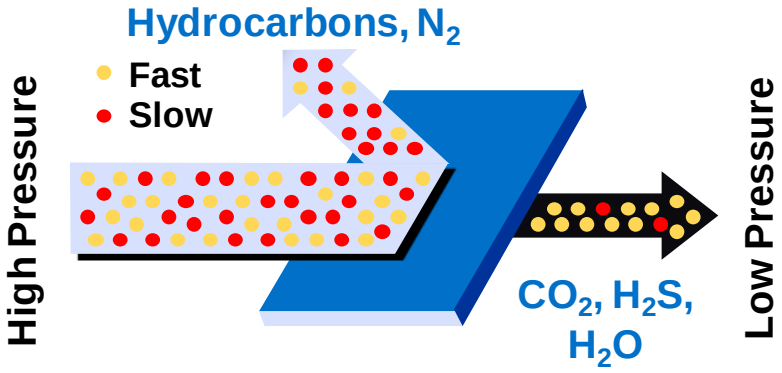
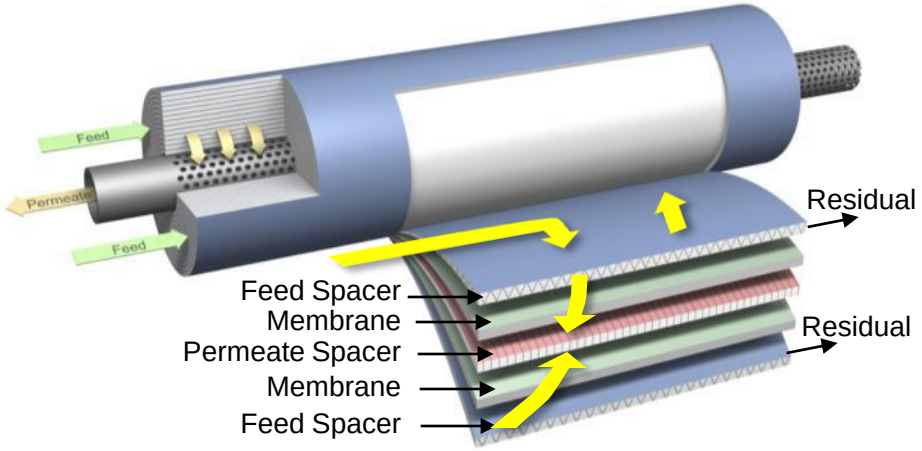
Membranes are:

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

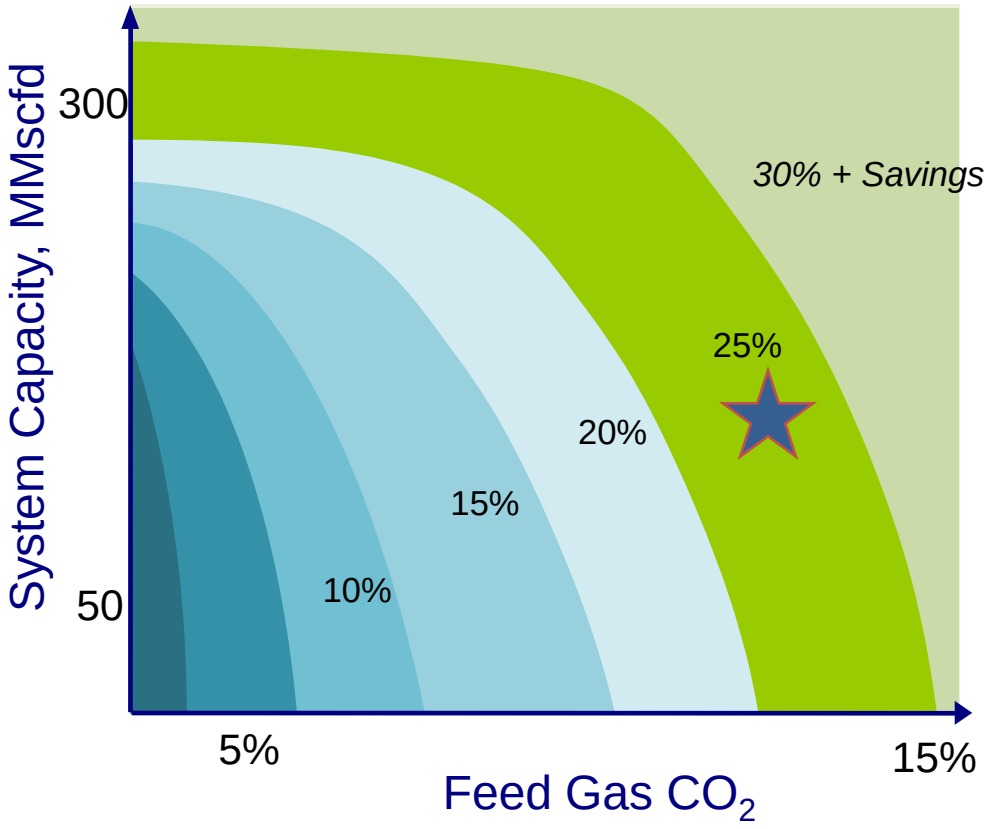
Membrane Process





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 Separex 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

Hydrocarbon Management Solutions

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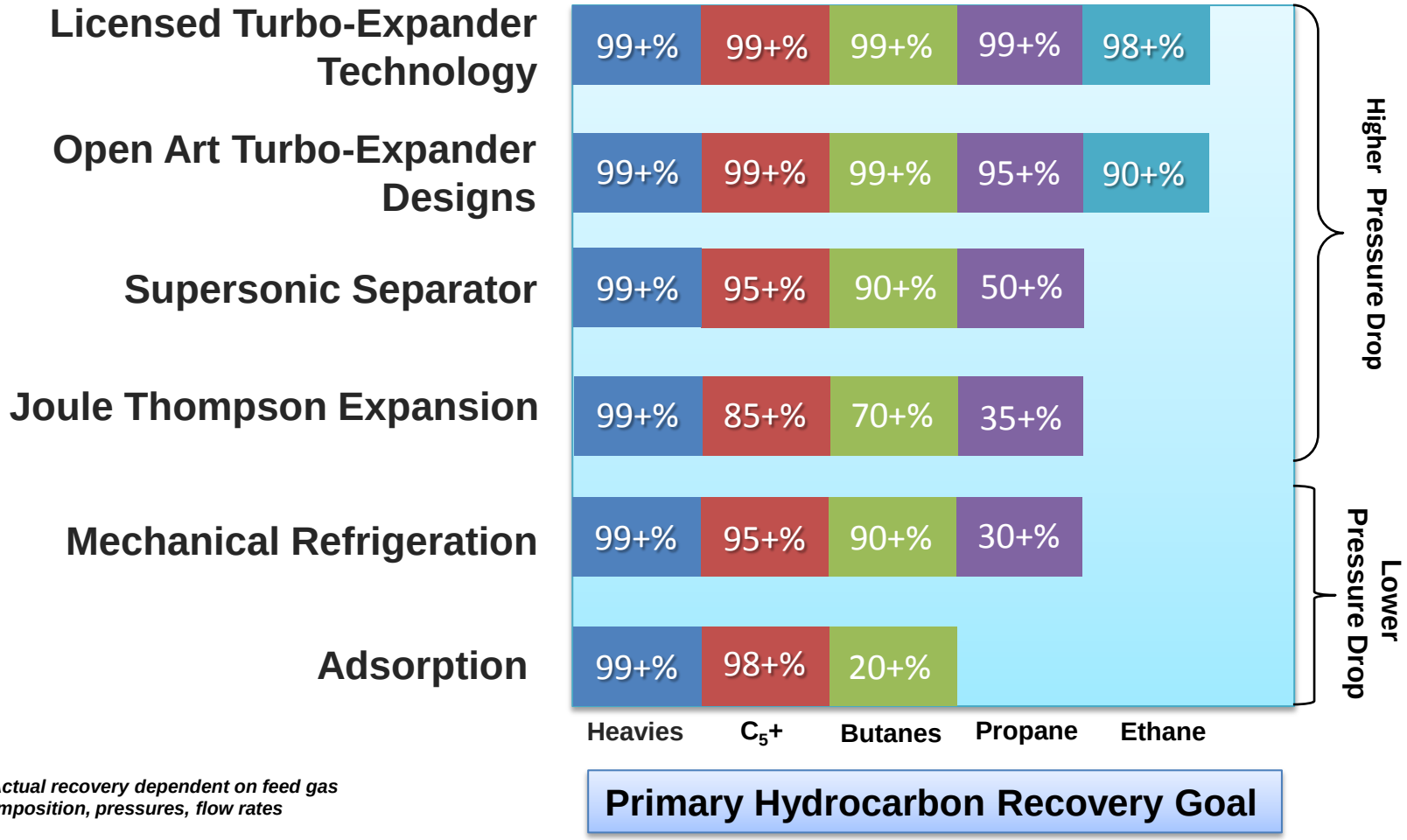
C_2+ Gas Processing

% Typical Recovery**



***Actual recovery dependent on feed gas composition, pressures, flow rates*

Primary Hydrocarbon Recovery Goal

A Broad Portfolio to Fit your HC Recovery or Removal Requirement

Gas Treating Summary

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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

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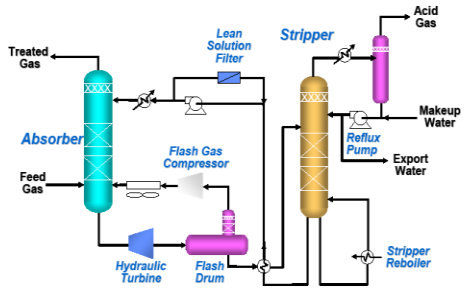
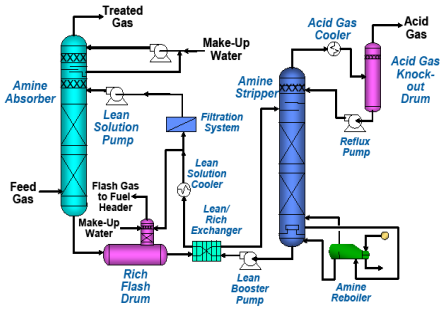
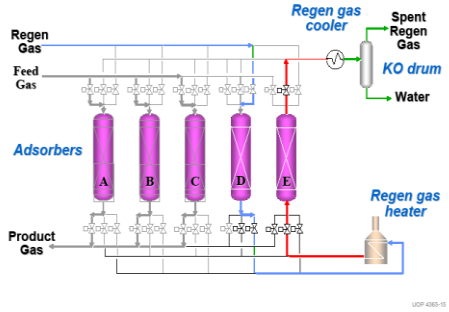
UOP SELEXOL™ Process



UOP Amine Guard™ FS Process



UOP Natural Gas MOLSIV ™ Process



Picture by courtesy of RASGAS

Modular Fabrication Solutions

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Key Technology Innovations

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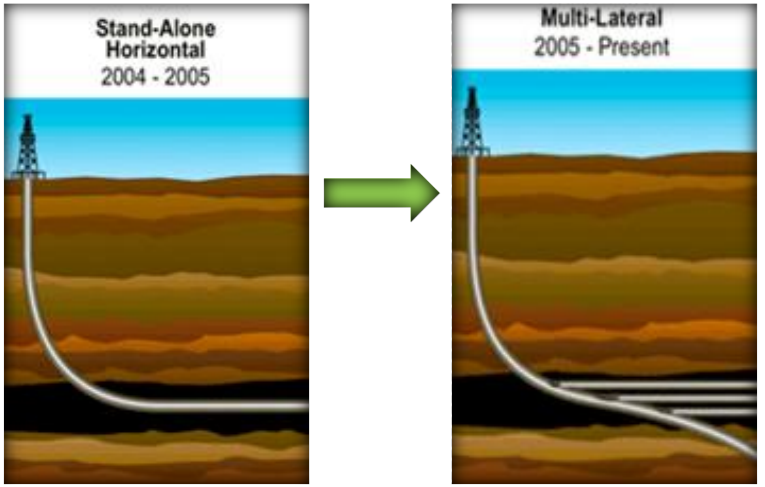
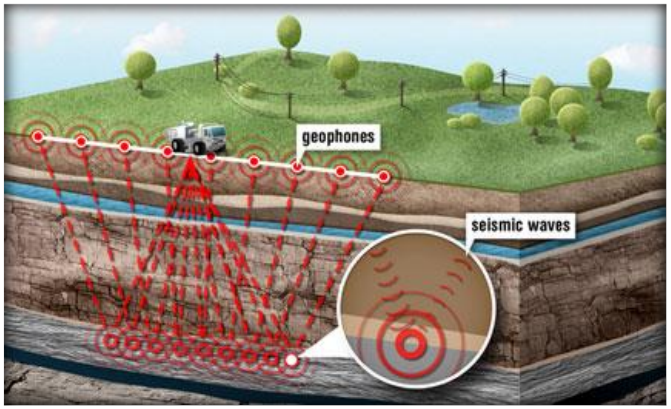
Hydraulic fracturing

Horizontal Drilling



Seismic Imaging



"Fast gas" NGL Recovery

What We Mean with Modular Design

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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"

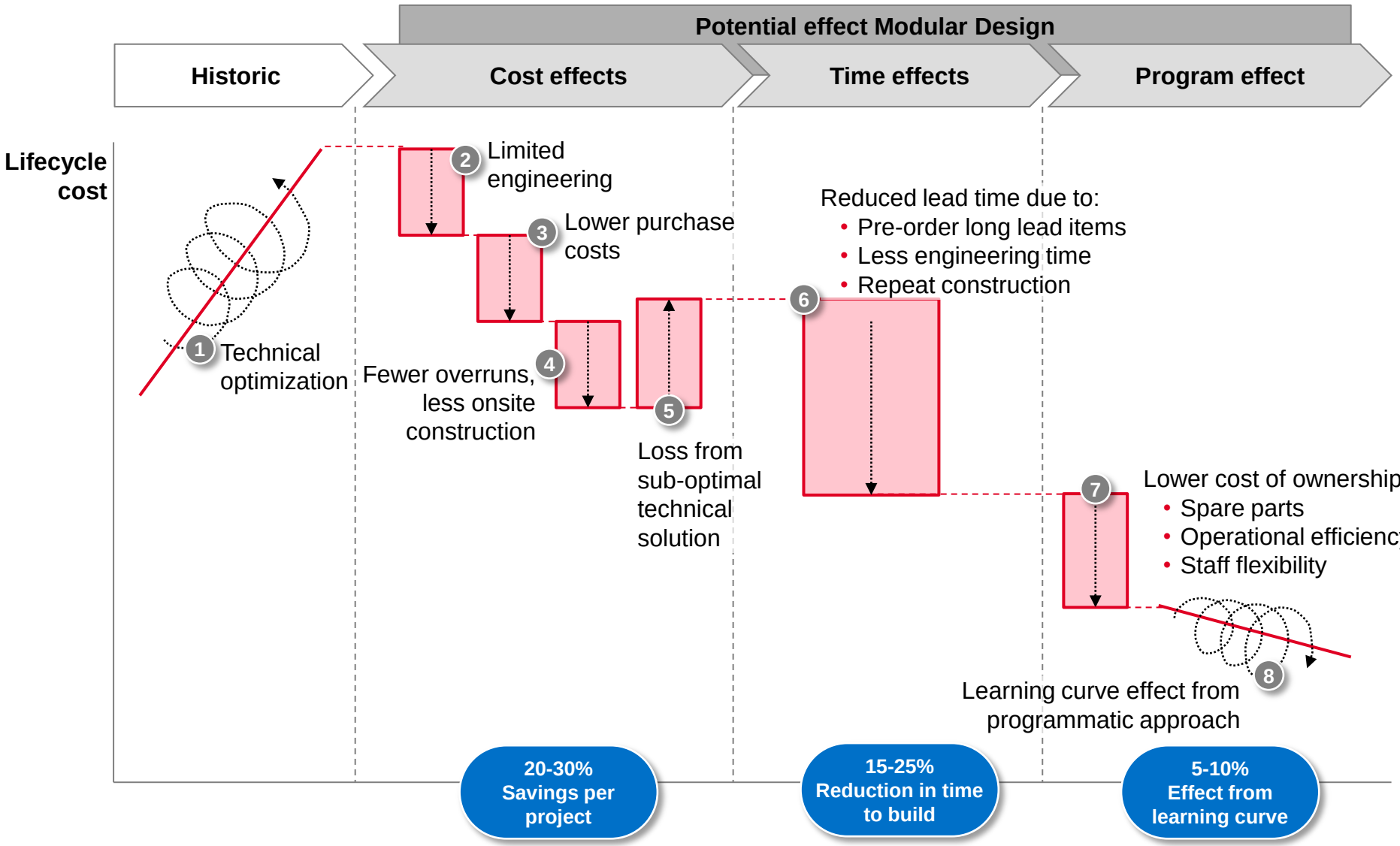
Key definitions within Modular Solution

- **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

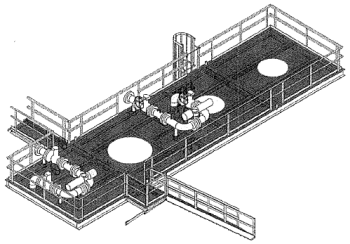
Modular Solutions Increase Overall Lifetime Value

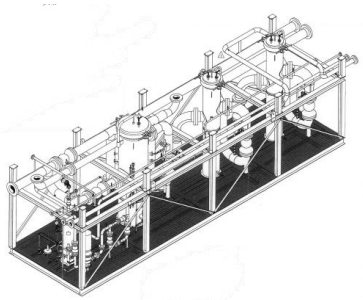
CONCEPTUAL

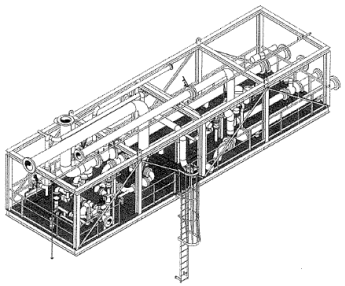


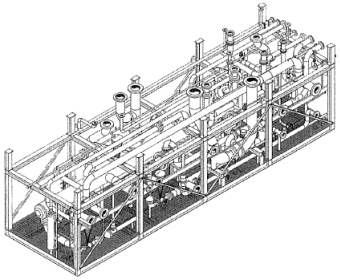
SOURCE: Based on UOP estimation and various oil and gas industry examples

Cryogenic Plant Skids



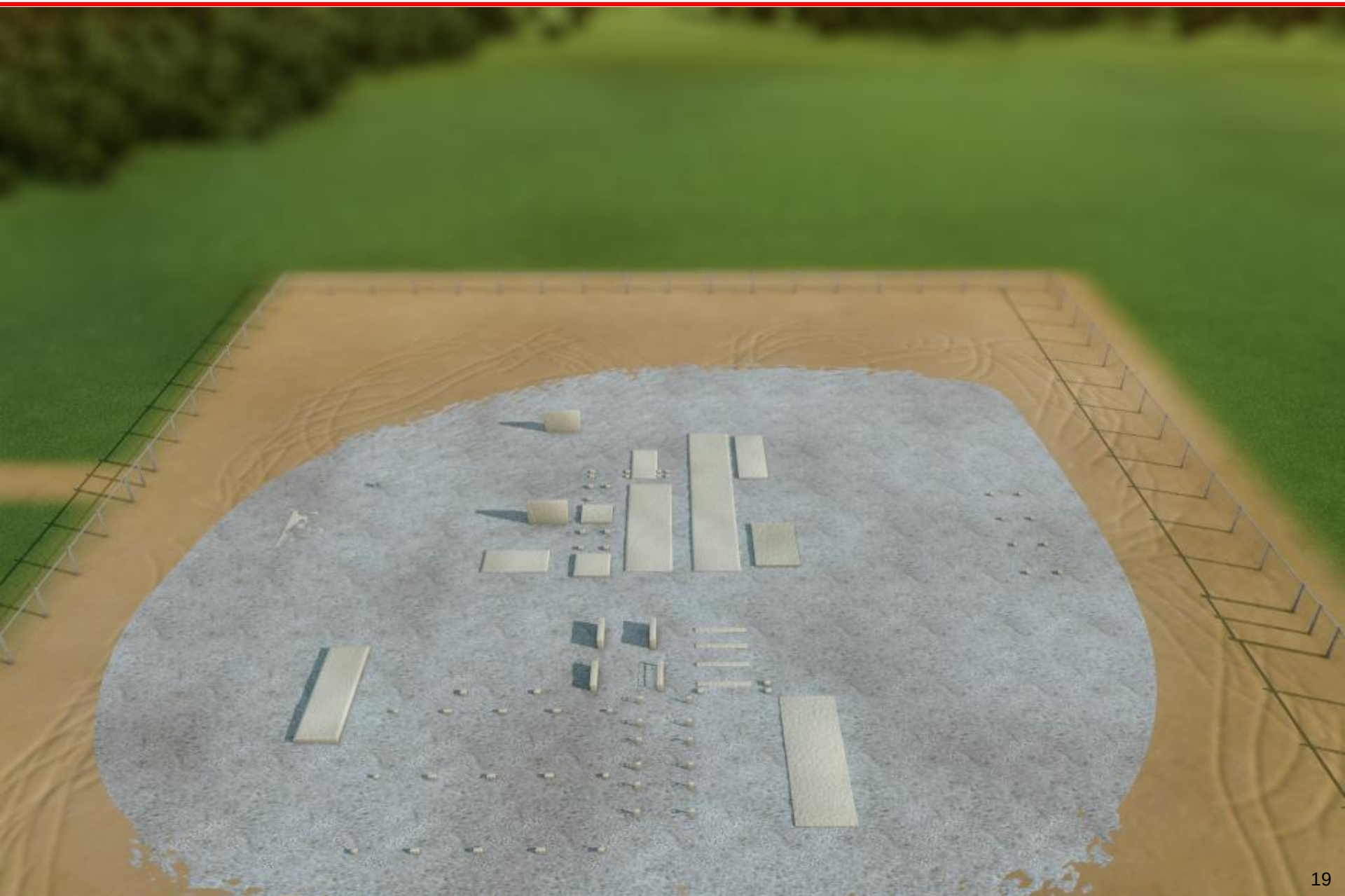






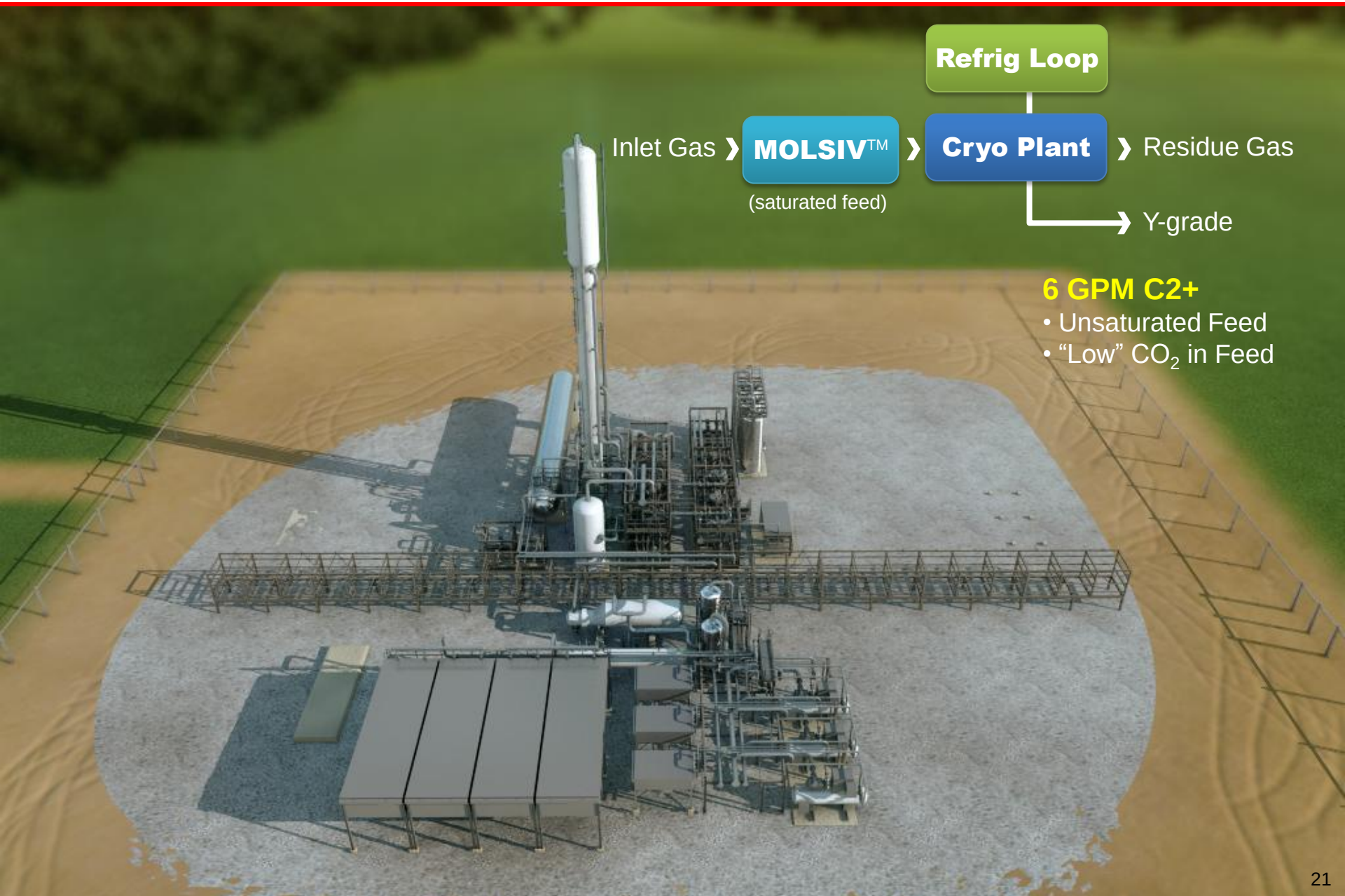
Skids are Factory Built and Ready for Installation Saving up to 20-30% per Project

Field Design Support Package

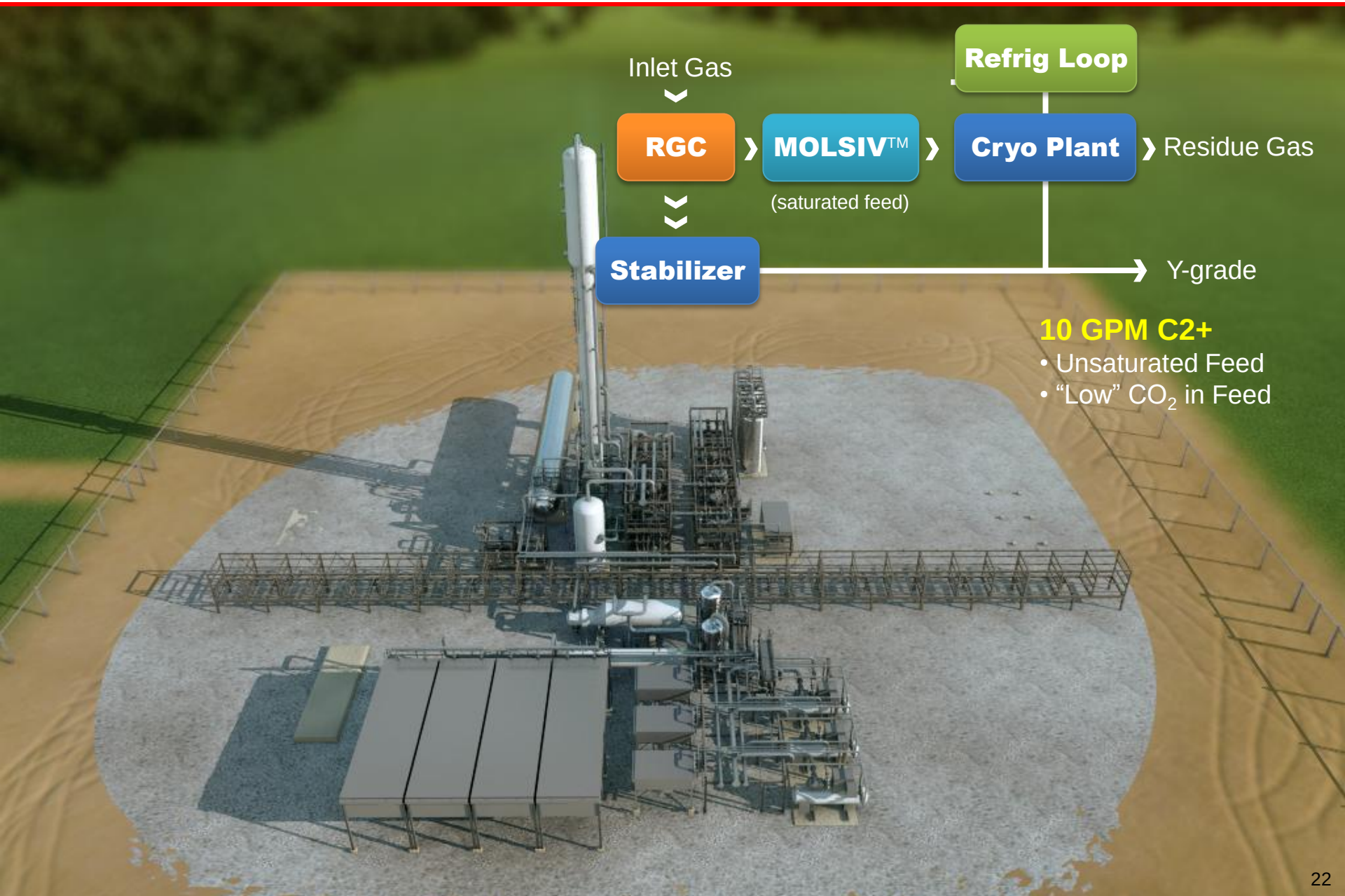


Standard Cryo Plant

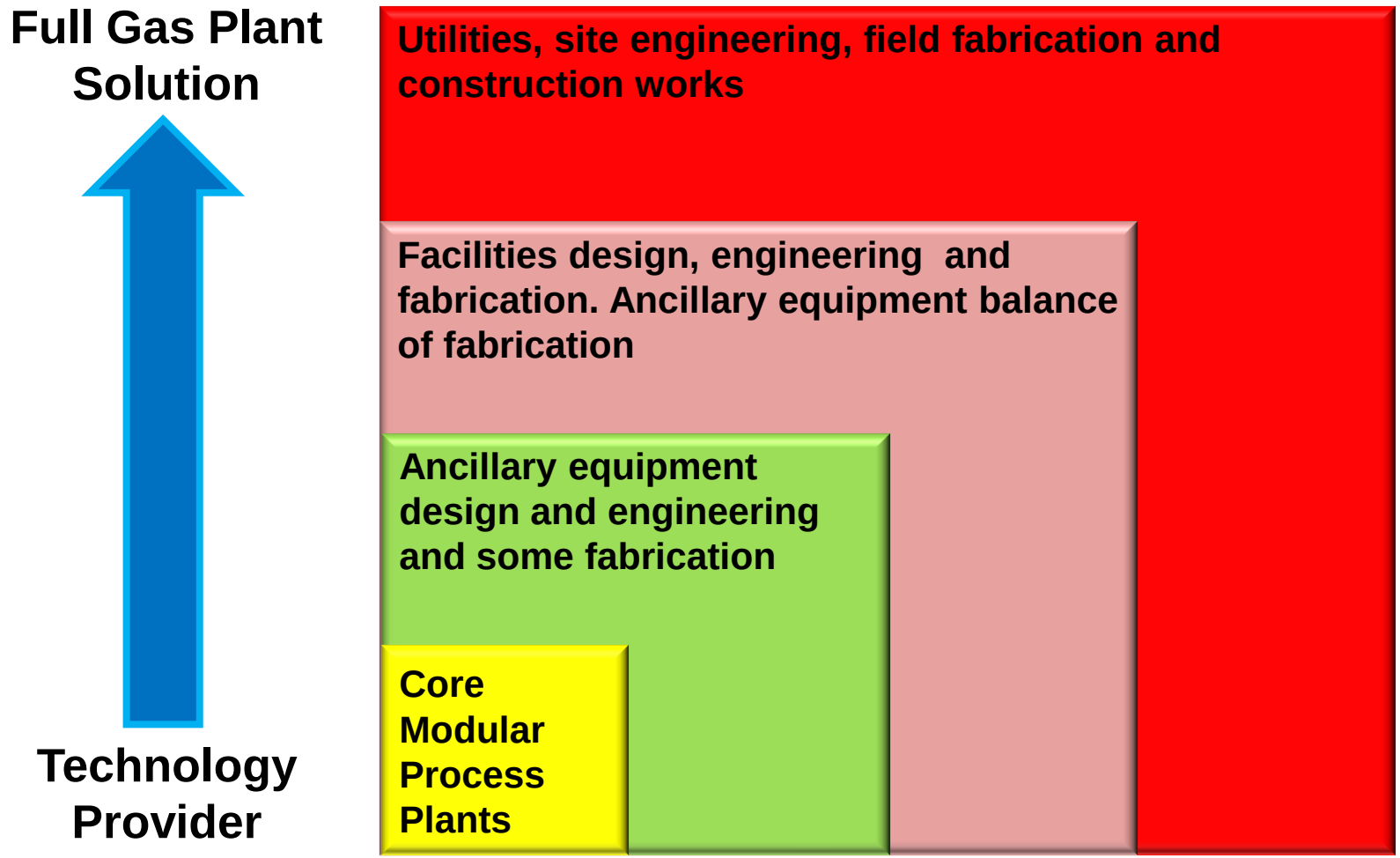
Standard Cryo + Mechanical Refrigeration (MR)



Standard Cryo + MR + Rich Gas Conditioner



Scope Definition Starts with….



Core Modular Process Plants

Rapid NGL Recovery Improves Return on Investment

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- **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**

Example

Shale Gas

200 million cubic feet per day (MMcf/d)

@ 3GPM NGL's

	Barrel Comp	Price Basis[123]	Value over fuel $M/month
Methane		Fuel Value	$0.0
Ethane	67%	Fuel Value	$0.0
Propane	15%	73% of crude	$2.7
n-Butane	4%	83% of crude	$0.8
i-Butane	5%	81% of crude	$1.0
Natural Gasoline	9%	74% of crude	$1.3

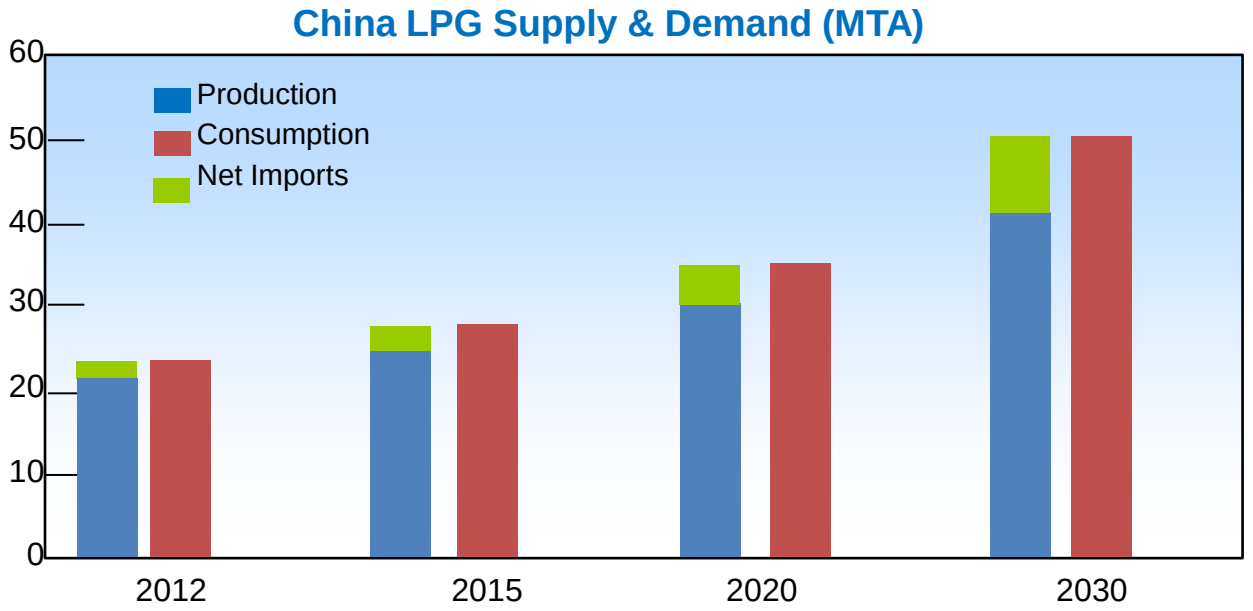
Amount Generated Monthly

$5.8MM

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

Modular Plants – Faster Delivery, Enhanced Value

China LPG Opportunity



Comments

- **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**

Increased Gas Processing Capacity for Enhanced LPG Supply

In Closing….

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A Complex Natural Gas Value Chain

Varying Natural Gas Reserve Compositions and Geographies

Diverse Gas Treating needs that Require Fit for Purpose Technology and Delivery Models

UOP Company Profile

Serving the Gas Processing, Refining & Petrochemical Industries

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Profile — Significant Technology Position

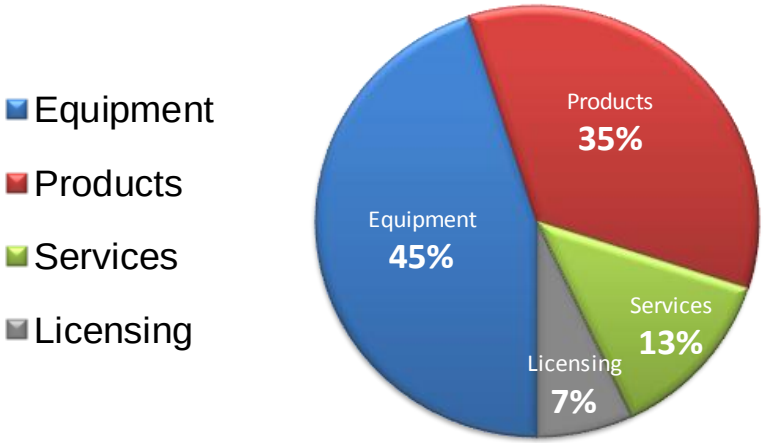
Business Units:

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

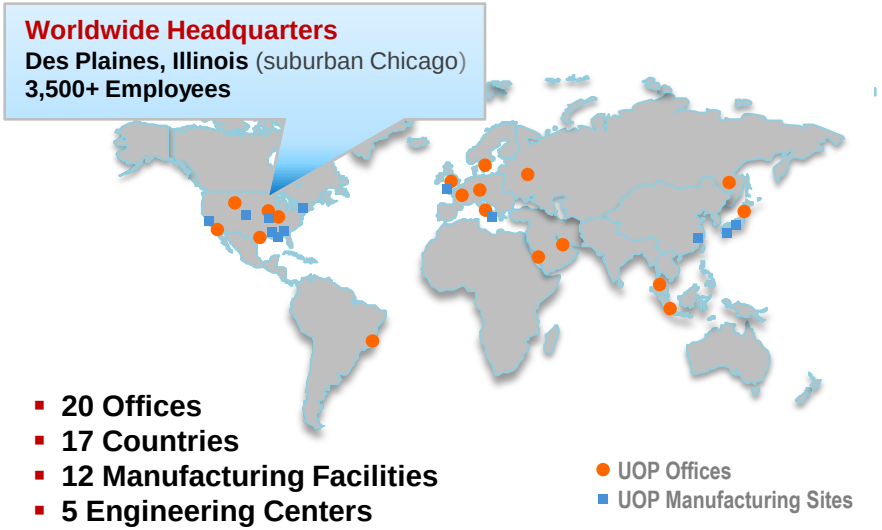
Offering:

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

Sales: Breakdown



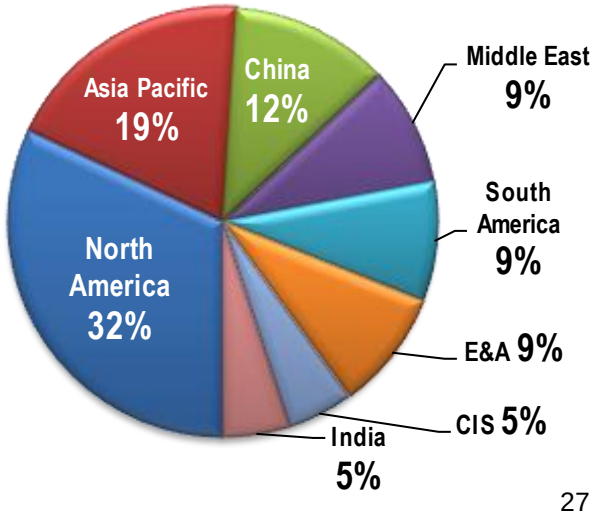
UOP Facilities — Global Footprint



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

Sales: Geographic

Global Customers



Q&A

Question and Answer