# Process Technologies: Leveraging the Transformational Shift

## Ethylene. LNG. Gas Processing. Hydrogen.

Peter Armstrong
Vice President of Business Development – Selas Linde (Linde Engineering)
RGF Annual Forum, Houston, November 12, 2019

Making our world more productive

# You Don’t Want to Fall Behind

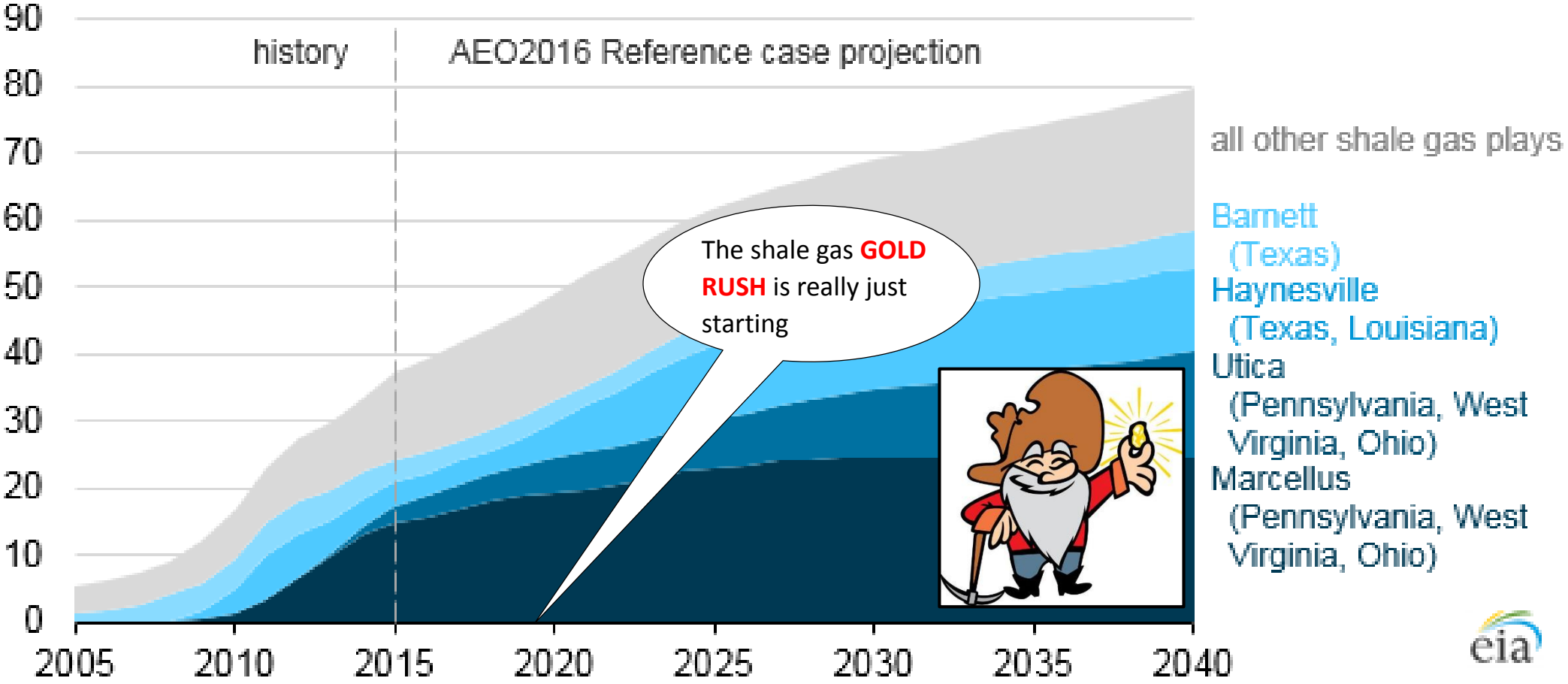
## ……on the Great Transformational Shift


*“Ryan’s a late adopter.”*

# The Great Energy Transformation

## …..is Just Starting

**U.S. shale gas production (2005-40)**
billion cubic feet per day



## The Great Energy Transformation

A Uniquely American Story (for now)

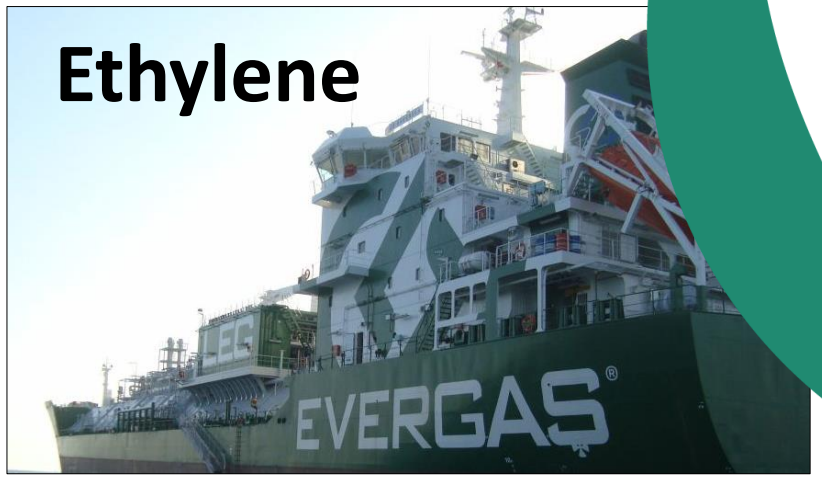
Unprecedented technology, economic, cultural, geopolitical & military impact

However…….

# An Abrupt Pivot

## …..to an Exploding Commodities Export Market






# The Great Energy Transformation

## *RIPPLE EFFECT*……through the Process Technology Industry

### ETHYLENE

### GAS PROCESSING

### LNG

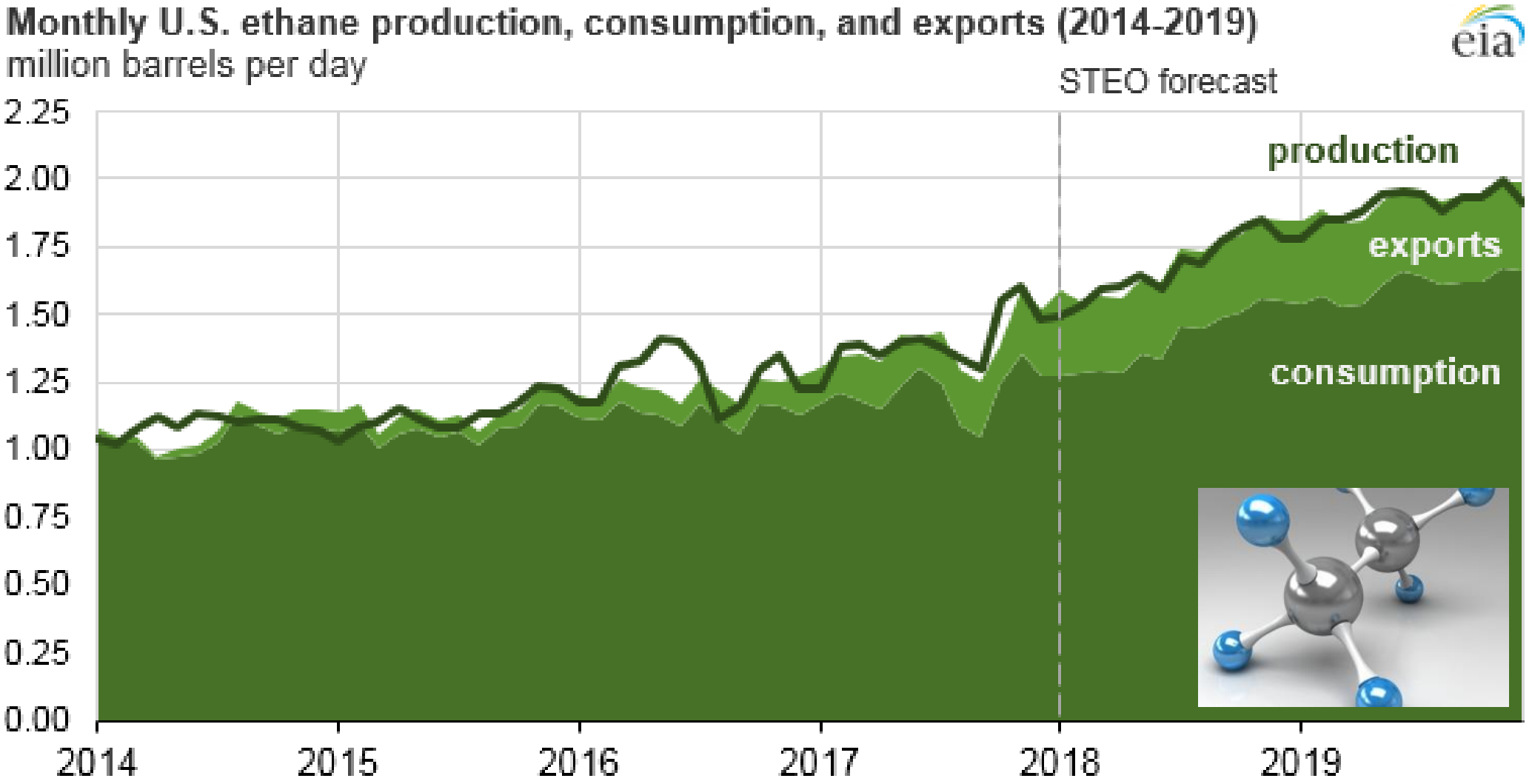
### HYDROGEN

## Cheap Ethane

Impact to the Ethylene Production Market

# Ethane Production Doubles in Five Years

## An Industry Renaissance → Explosive Growth



## Cracking Furnace

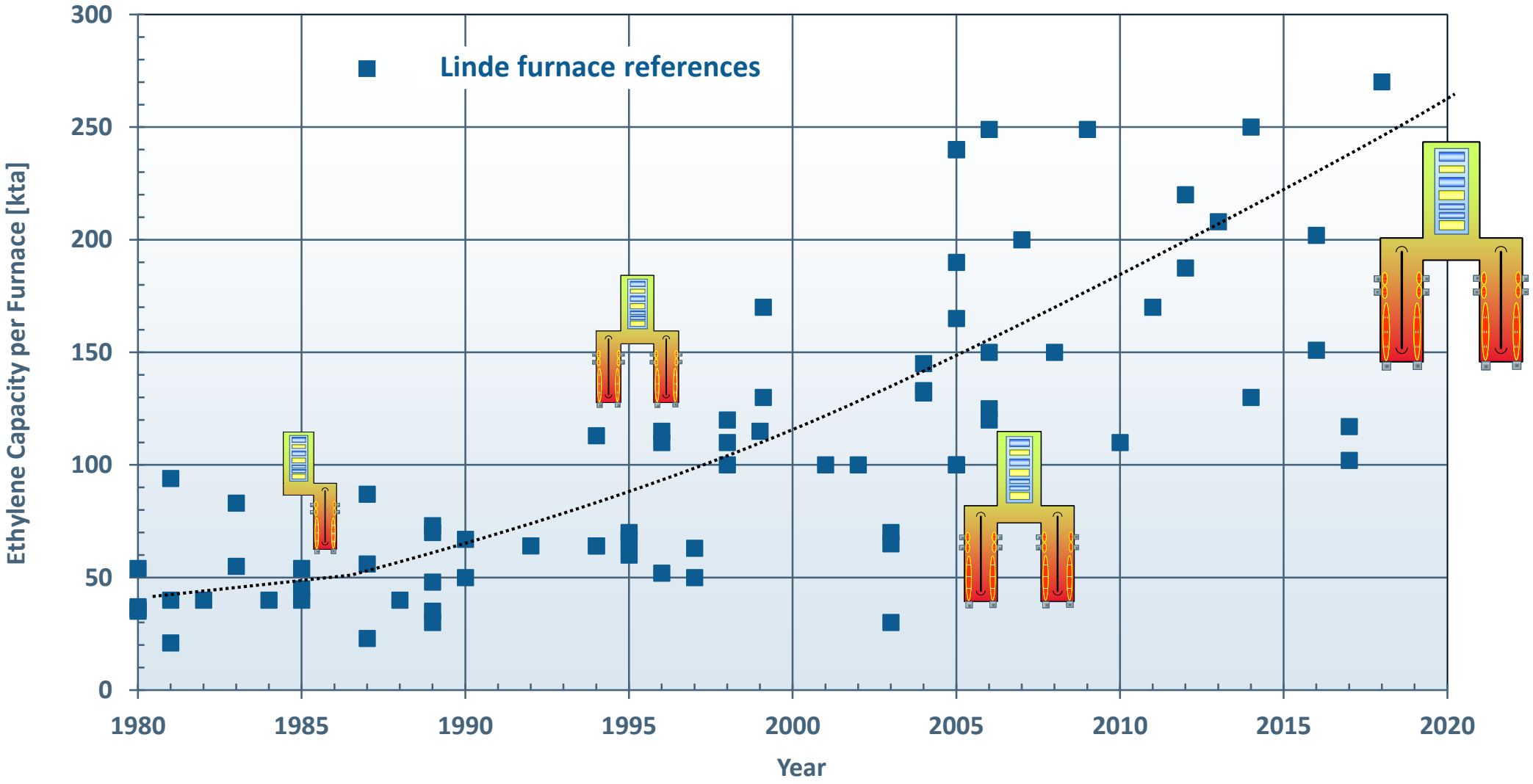
Process Design Drivers


## DRIVERS

- Efficiency
- Yield
- Conversion
- Residence Time
- Run Length
- Production
- Decoking
- Cost & Risk

# Linde Furnace Capacity Is Setting "World Scale"

## Getting BIGGER and **BIGGER** and **BIGGER**

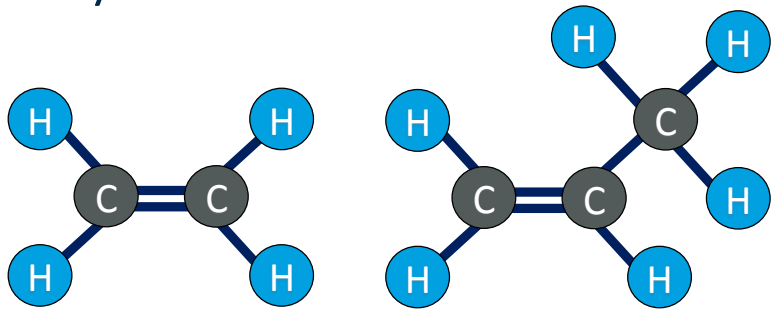


# Ethylene Furnace

## The Science of CRACKING Process Technology

## Process

- ❑ Feedstock and dilution steam preheat
- ❑ Cracking of hydrocarbons to produce valuable olefins by endothermic reaction



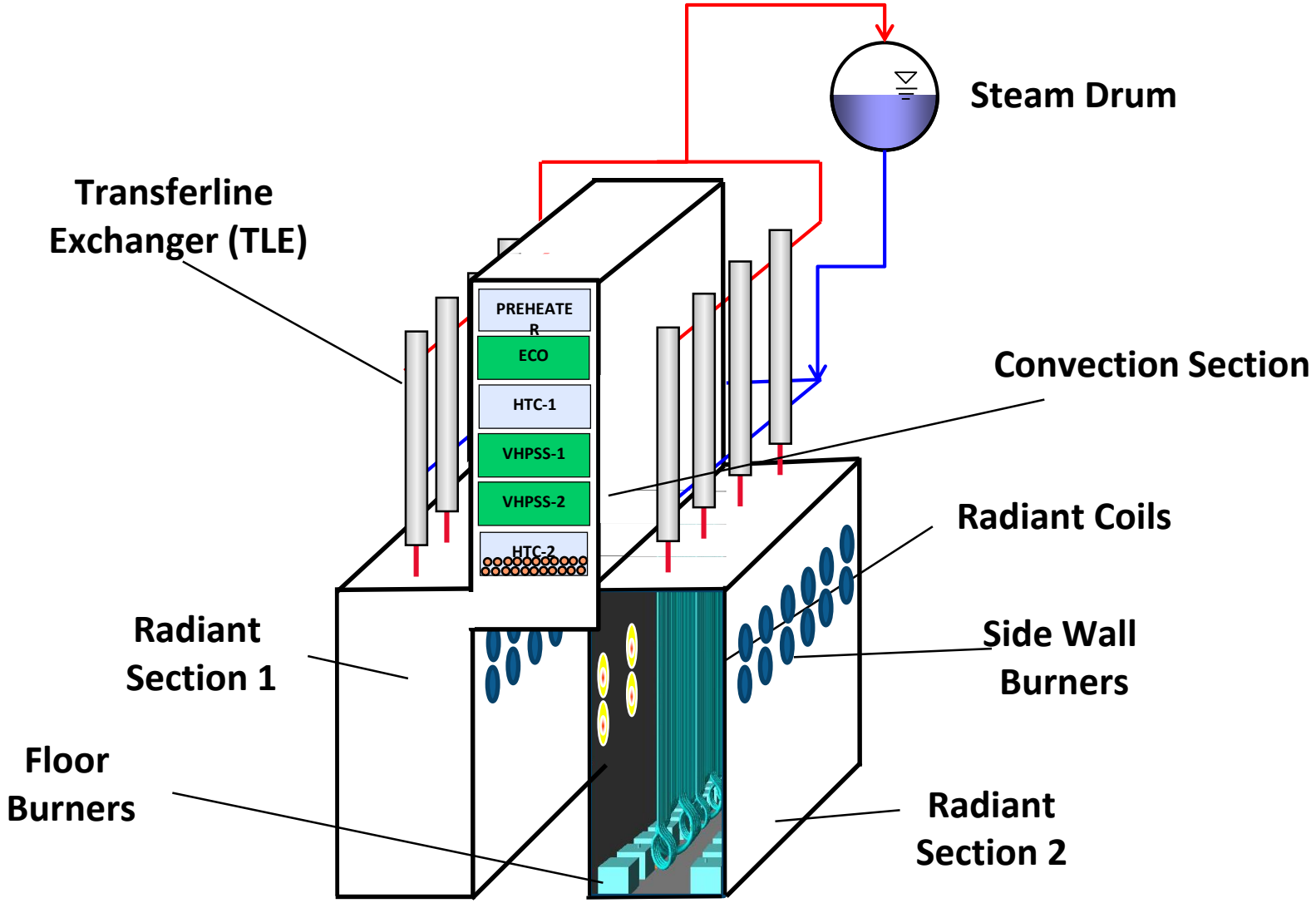

- ❑ Cooling of the cracked gas

## BFW & Steam

- ❑ Steam production by BFW preheat and HP-steam superheating

# Cracking Furnace

## Performance / Engineering Innovation Drivers

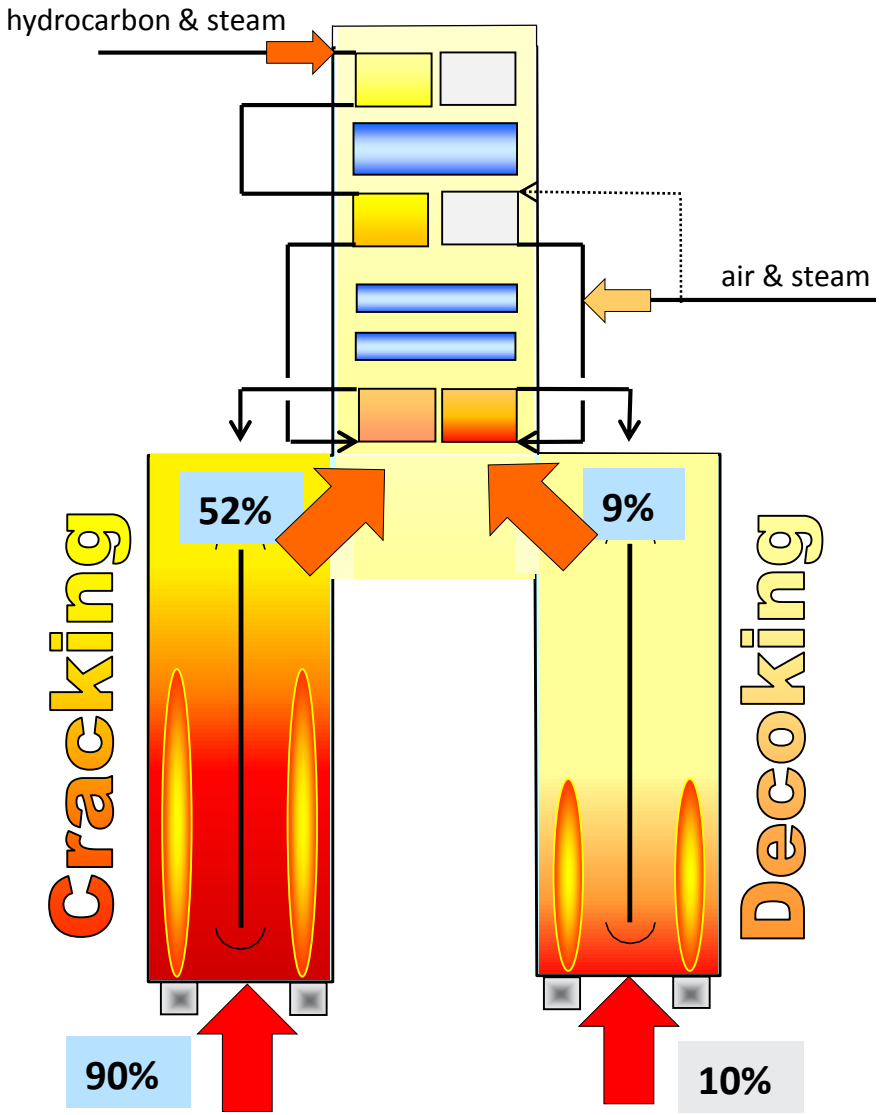



## *Performance Drivers*

- Efficiency
- Yield
- Conversion
- Residence Time
- Run Length
- Production
- Decoking
- Cost & Risk

# Cell Decoking Enhances Flexibility for High Capacity Furnaces

## Driver → Maximize Production Capacity




**One furnace cell in normal operation**

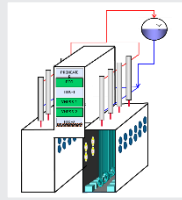
**One furnace cell in decoking mode**

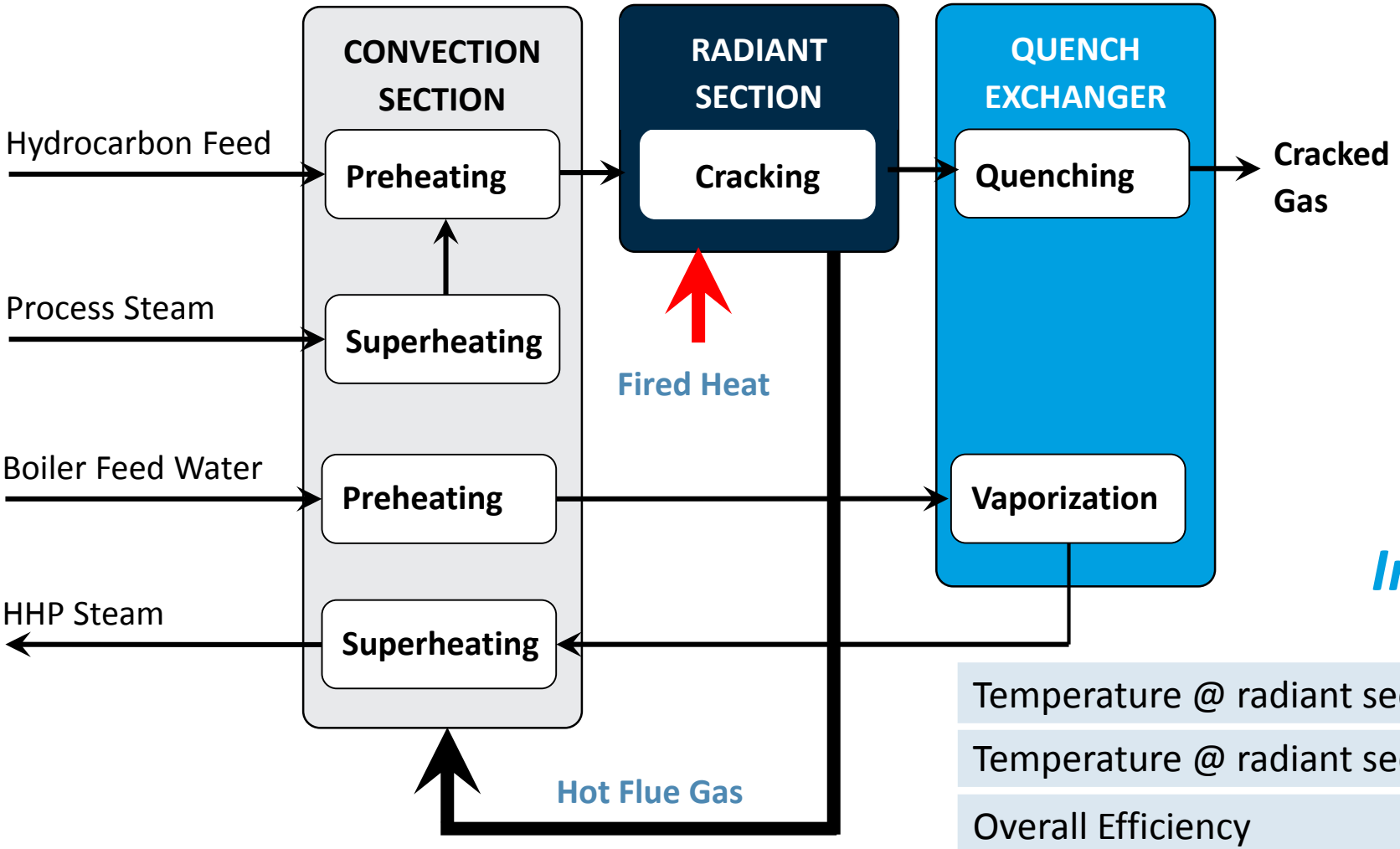
— Production remains at 50% during decoking

— Increased operational flexibility

# Cracking Furnace

## Driver → Overall Efficiency of Operation [93-95%]



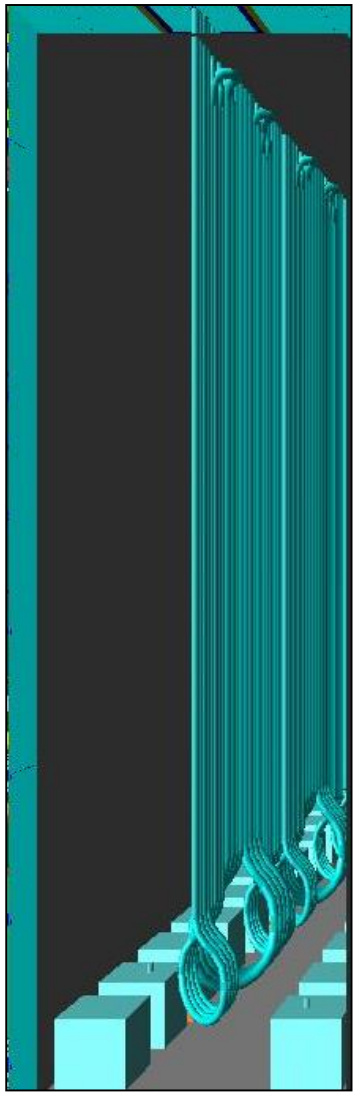



## *Innovation Drivers*

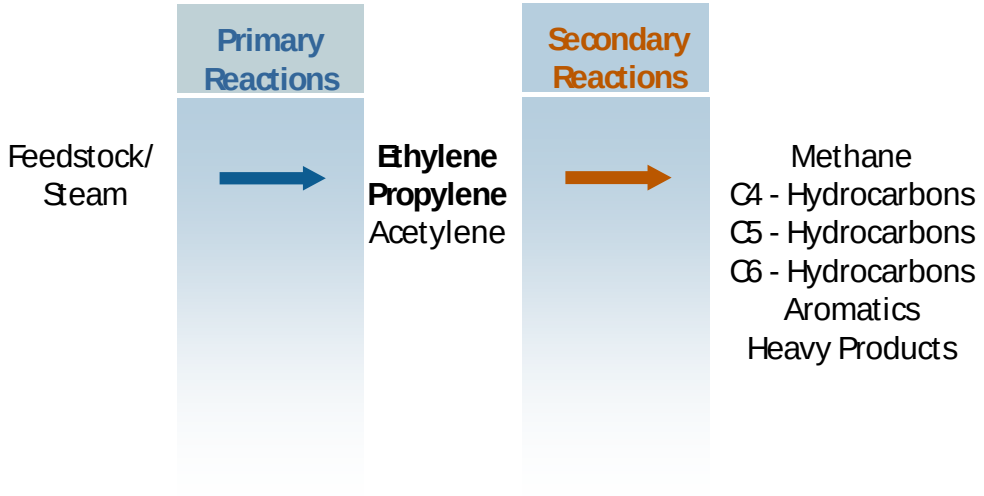
| | |
|---|---|
| Temperature @ radiant section inlet | 1076-1238 °F |
| Temperature @ radiant section outlet | 1472-1598 °F |
| Overall Efficiency | **93-95%** |

# It's All About the Coils

## Drivers → Selectivity, Run Length, Efficiency, Other…..



## The coils are the heart of technology differentiation

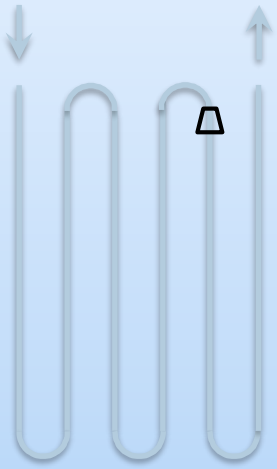
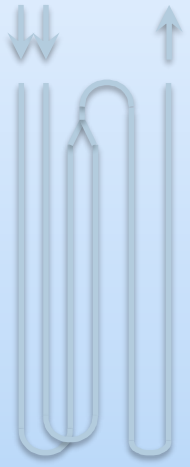
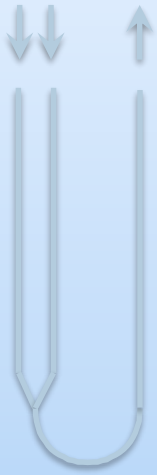



### Process Objectives

- High Selectivity to Olefins
- Capacity & Run Length
- Wide Feed Flexibility & Product Spectrum
- Efficient Energy Utilization

# Coil Design Options: PyroCrack™ Radiant Coils

## Driver → Coil Selection / Optimization

| PyroCrack Coil Type | 6 | 2 - 2 | 1-1 |
|---|---|---|---|
| Schematic arrangement |  |  |  |
| Residence Time [sec] | 0.40 - 0.65 | 0.25 - 0.45 | 0.15 - 0.30 |
| Tube I.D. [mm] | 90 - 125 | 65-90 / 90-125 | 35-60 / 50-80 |

Application preferred for

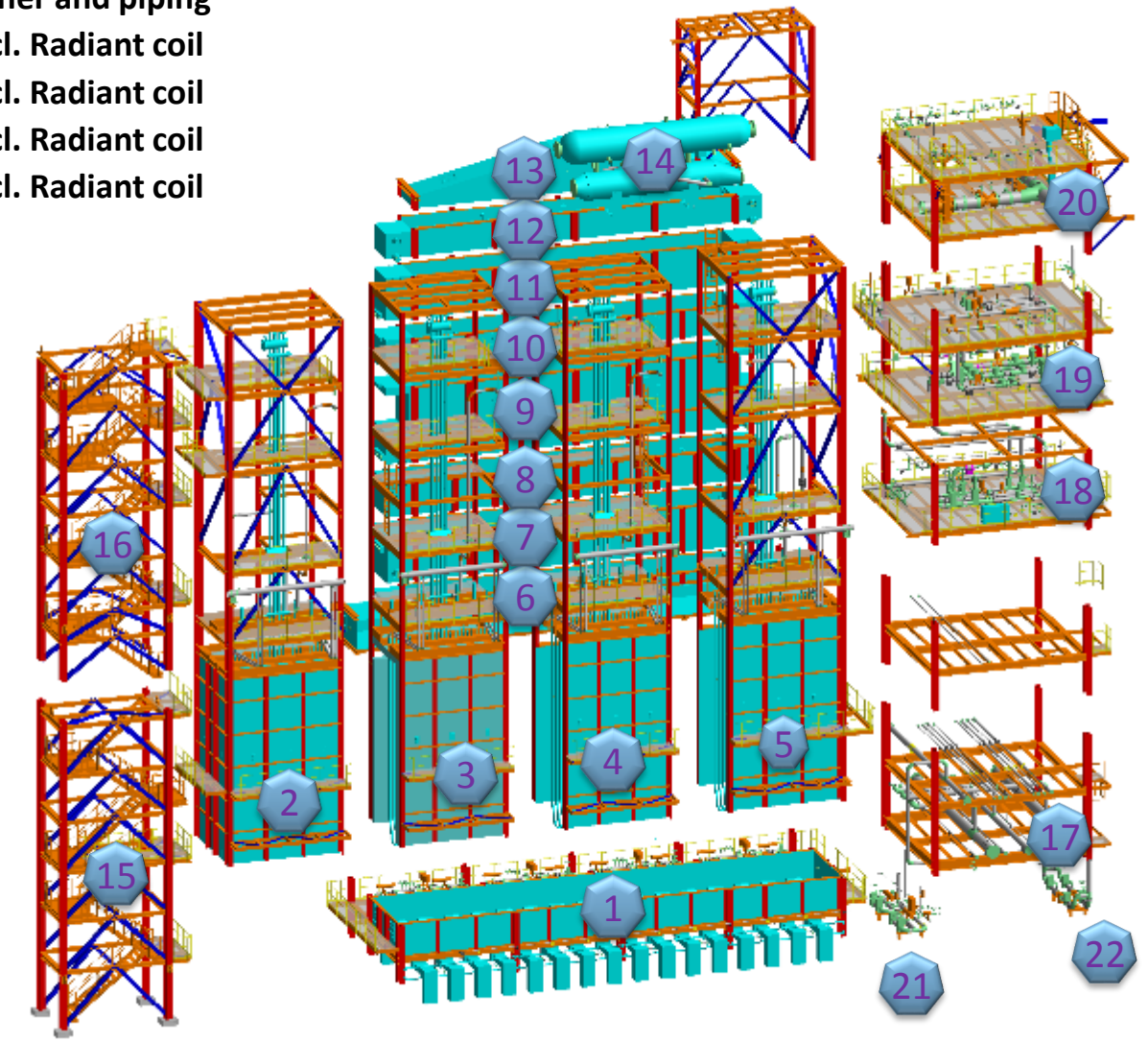
# Modularization - BP Gelsenkirchen

## Drivers → Total Installed Cost & Construction Risk

# Truckable Single Cell Ethane Cracking Furnace

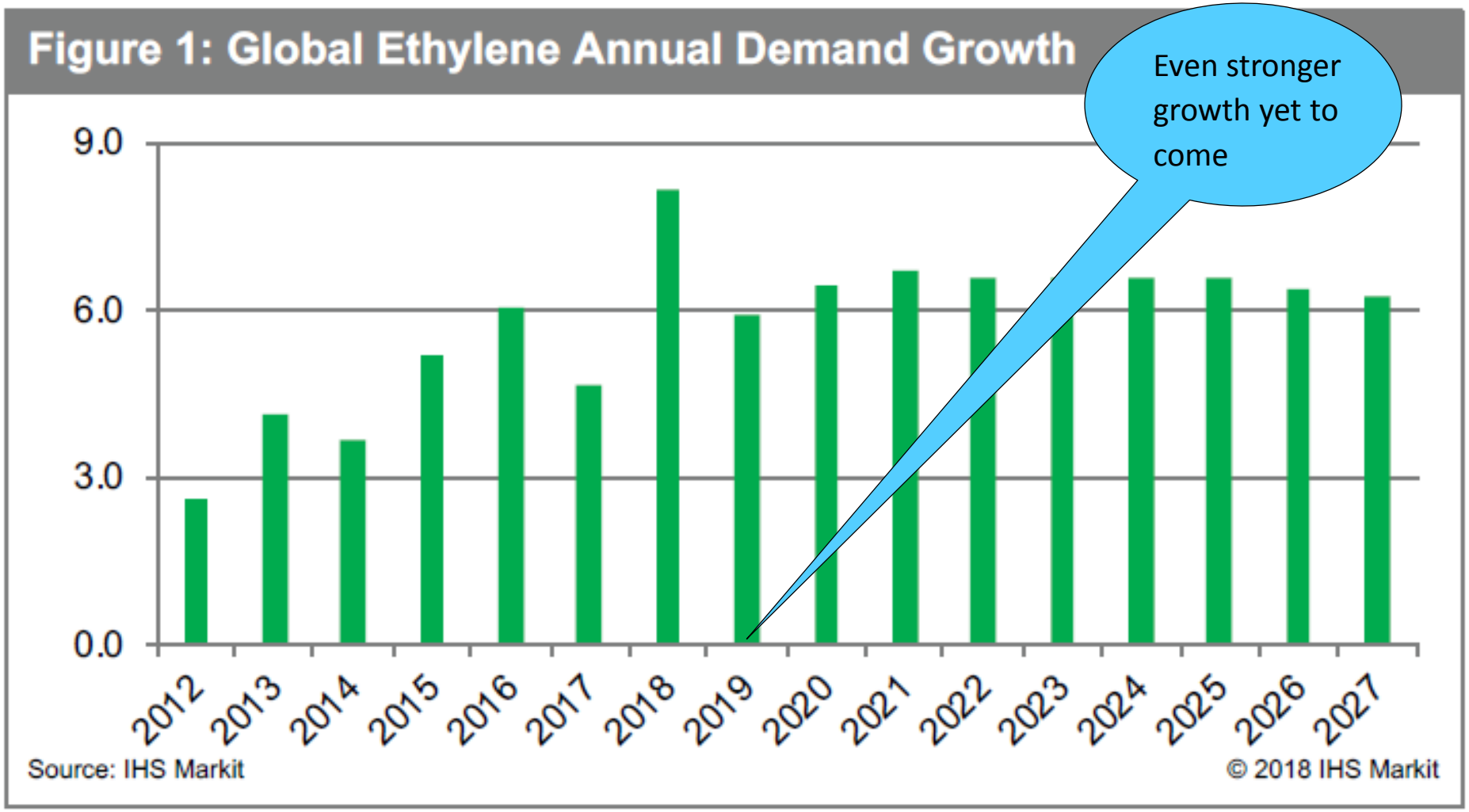
## Innovation at its Best

**1 – Radiant Section Bottom, incl. burner and piping**
**2 – Combined rad box and TLE #1, incl. Radiant coil**
**3 – Combined rad box and TLE #2, incl. Radiant coil**
**4 – Combined rad box and TLE #3, incl. Radiant coil**
**5 – Combined rad box and TLE #4, incl. Radiant coil**
**6 – Convection module #1**
**…**
**…**
**13 – Convection modules #8**
**14 – Piggy-back Steam drum/SQE**
**15 – Stair Case bottom**
**16 – Stair Case top**
**17 – Pipe rack module #1**
**18 – Pipe rack module #2**
**19 – Pipe rack module #3**
**20 – Pipe rack module #4**
**21 – Valve Skid #1**
**22 – Valve Skid #2**



# Ethylene Production

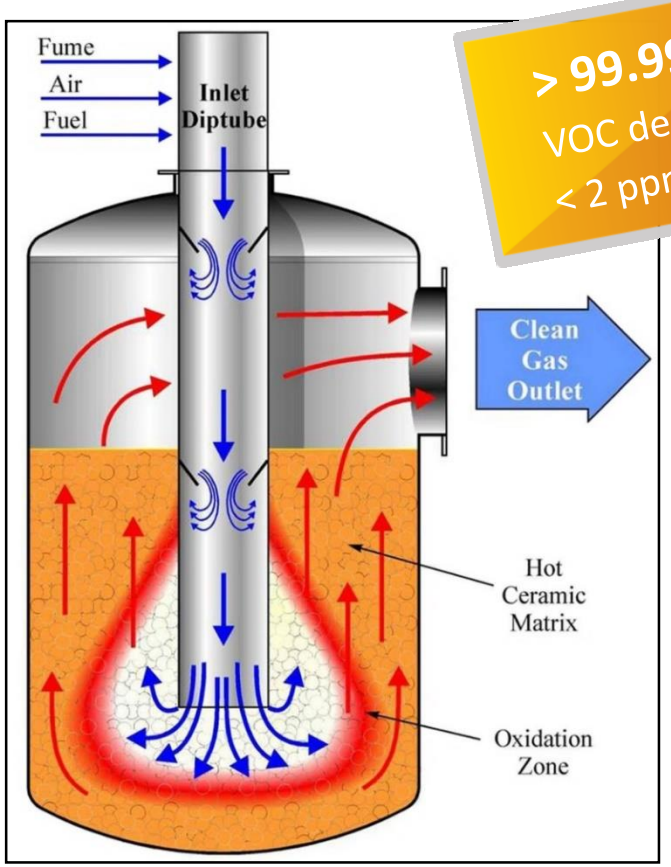
## Our Best Years Are Still Ahead



## All this Production Growth Leads to……

Increased Gaseous & Liquid Waste……"we have a plan for that"

### Flameless Thermal Oxidizer



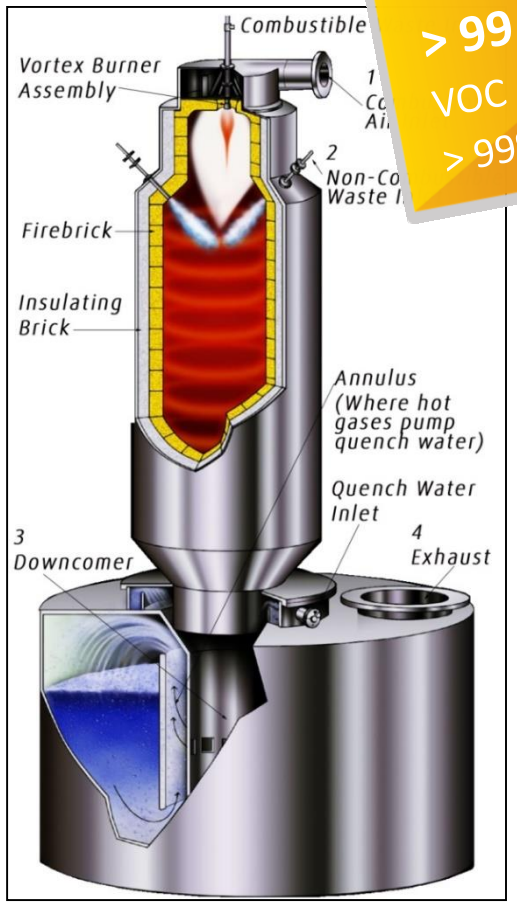

> 99.999%
VOC destruction
< 2 ppm NOx

# Emissions Control Technology

**Near Zero Emissions**

**for a**


### Sub-X Oxidizer




> 99.999%
VOC destruction
> 99% availability

# First Wave, Second Wave, Third Wave, Fourth Wave???

## How Long Will the Ethylene Party Last?

# LNG

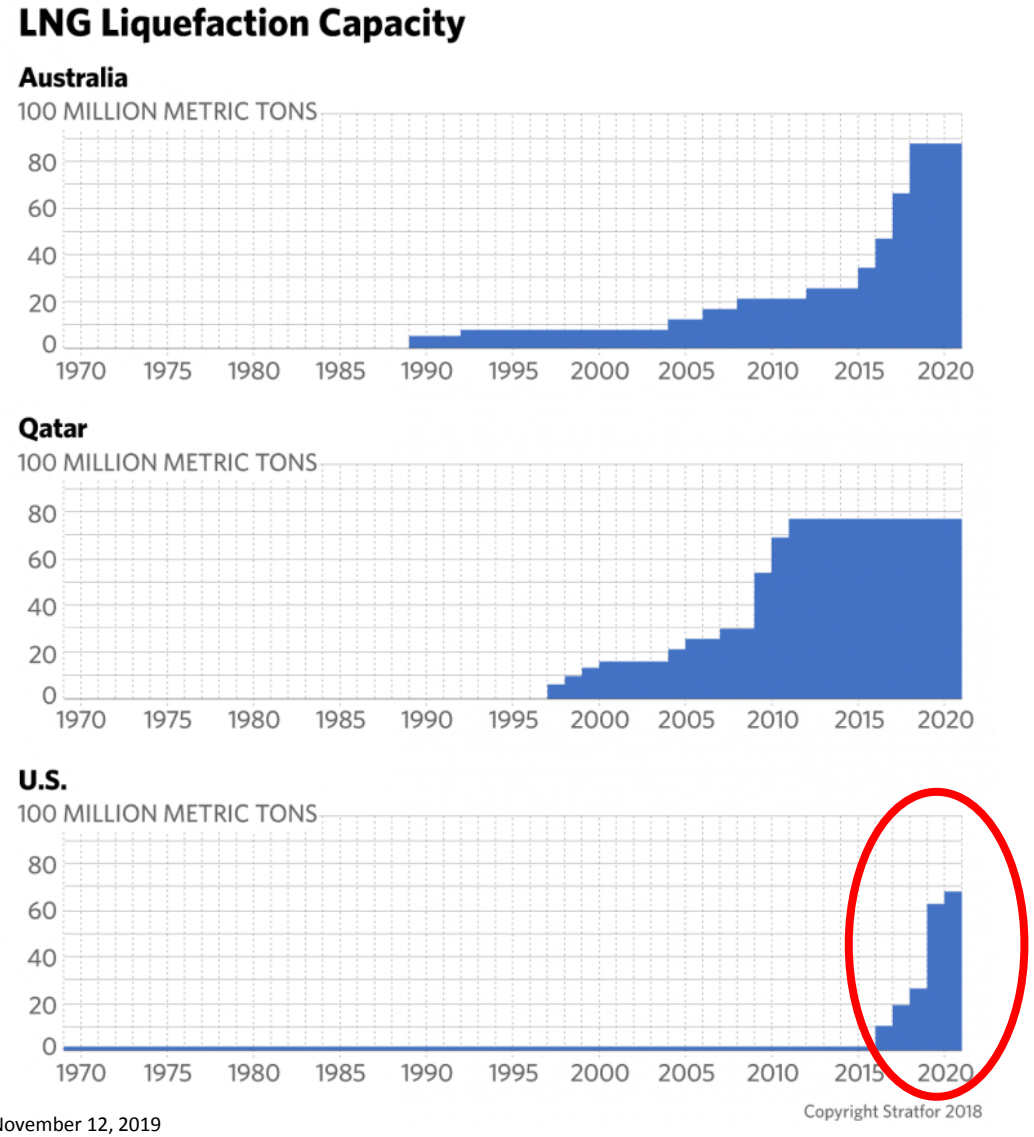
## Impact to the LNG Industry: Domestic Consumption, Imports, Exports

## Almost a 100% Pivot in the U.S.

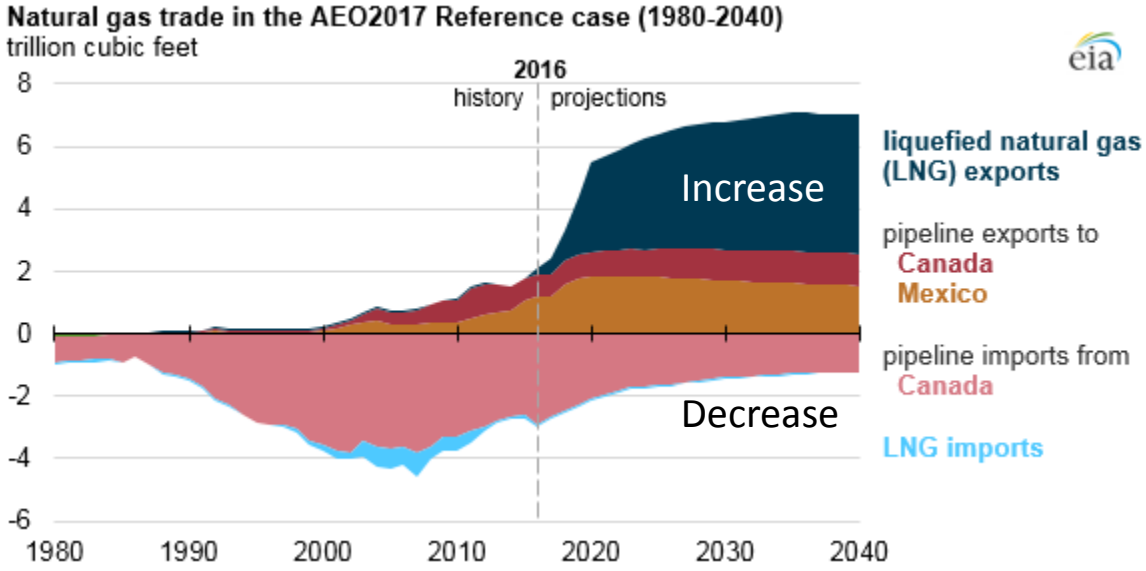
Heads are Still Spinning


# United States LNG Exports

## How Dramatic is This Pivot?




# Natural Gas Trading
# Imports & Exports



# Natural Gas Liquefaction

## Why Does LNG Continue to Grow?


### LNG is a diverse market

- Import / Export
- Peak shaving
- Virtual pipeline / distribution
- Trucking / Marine
- Flare gas solution

### Market drivers

- Cheap shale gas
- Natural gas demand growth
- Ability to store
- Environmental – clean energy

### Performance drivers

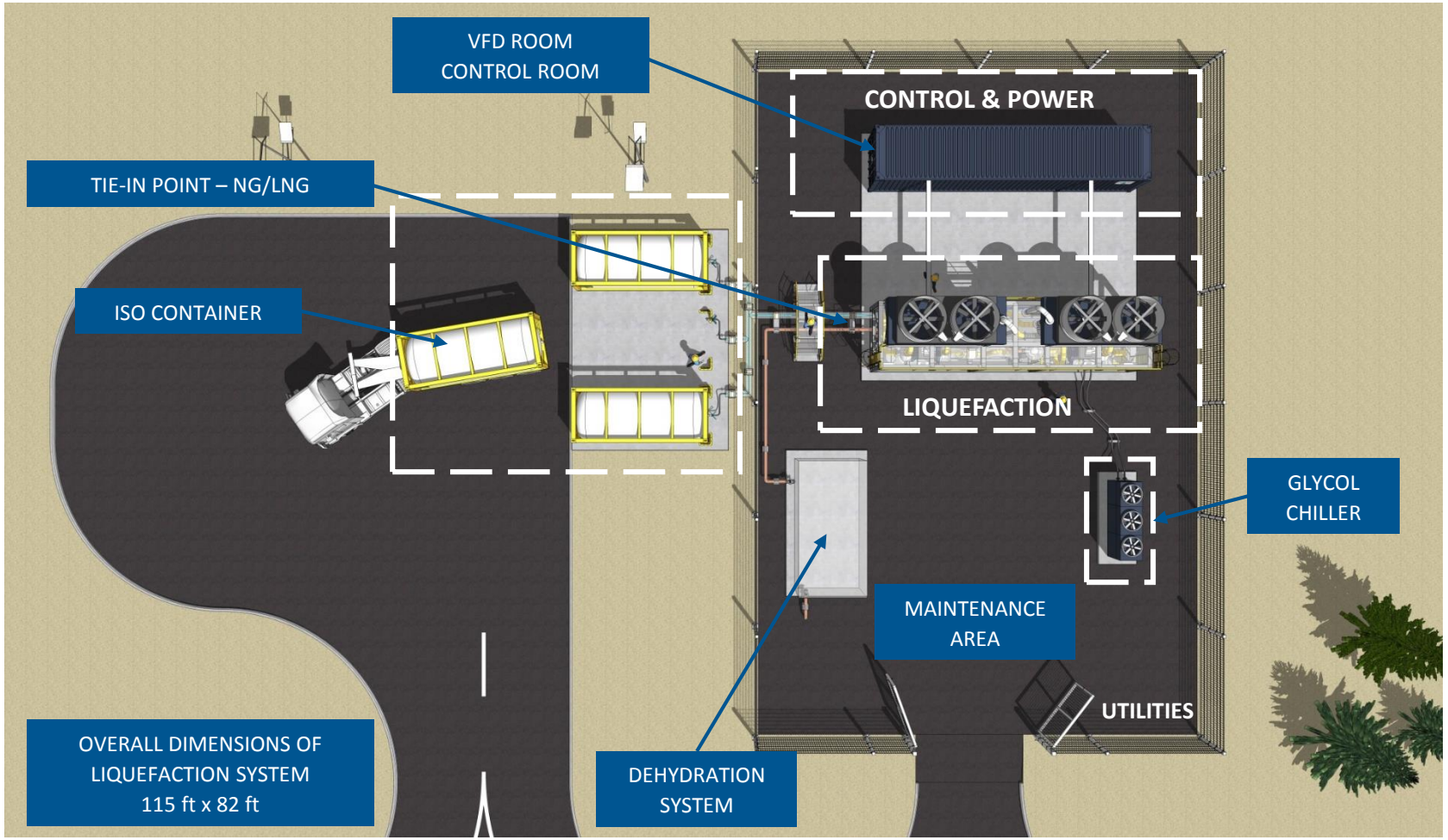
- Standardization / cost
- Scalability
- Plug & Play
- Speed-to-market
- Operating reliability

# StarLiteLNG™ 6000 gpd (0.5 MMSCFD) LNG Plant

## Scalable, Plug & Play, Speed-to-Market, Standardized

*Due to the explosion in shale gas - - the market has become very fast moving*

StarLiteLNG™
Mini (10 TPD)



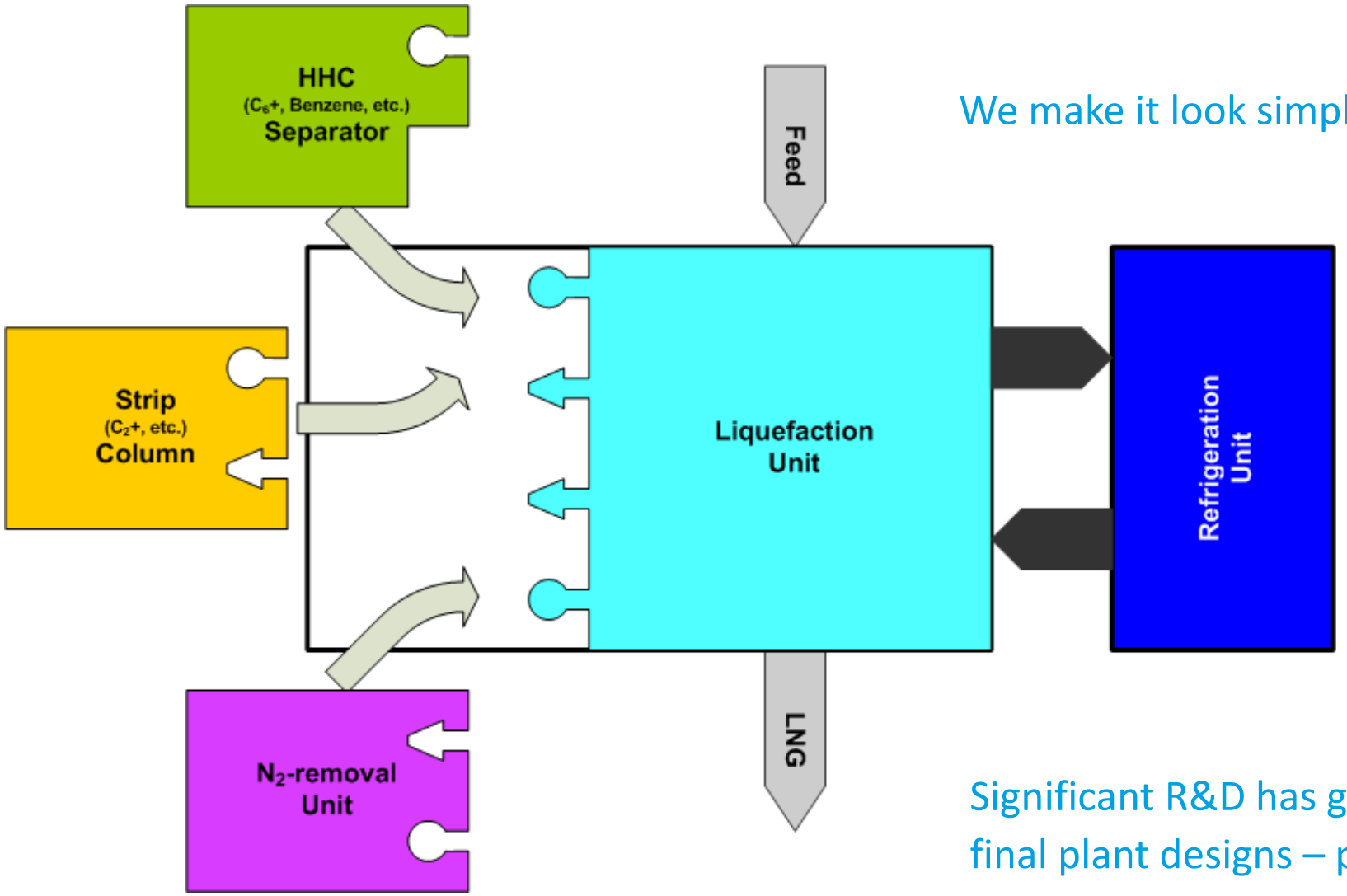

**SIZE MATTERS**

Now we're talking about

SMALL

# StarLNG™

## The Approach



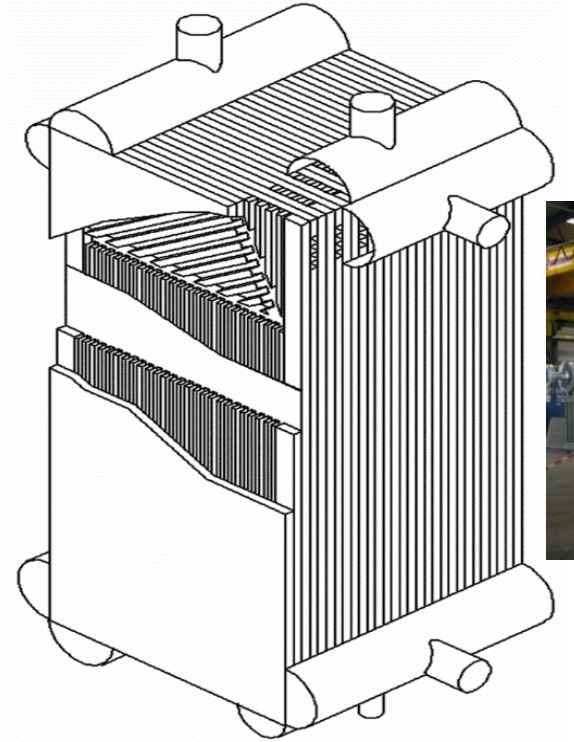

We make it look simple but it's really not

Significant R&D has gone into final plant designs – plug & play

# Liquefaction Technologies

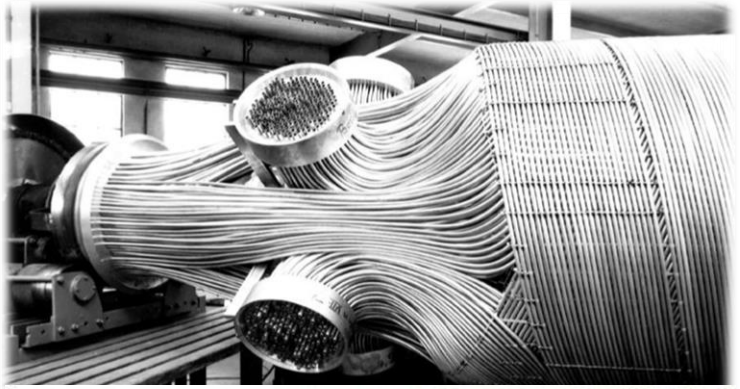
## Two Types of Cryogenic Exchangers

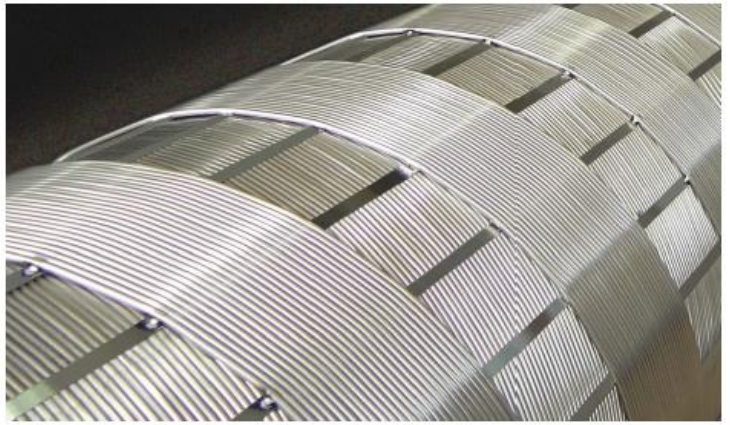
Plate Fin Heat Exchangers (PFHE)
"Brazed Aluminum" Heat Exchanger



Reliability is #1 driver

Coil-Wound Heat
Exchangers (CWHE)



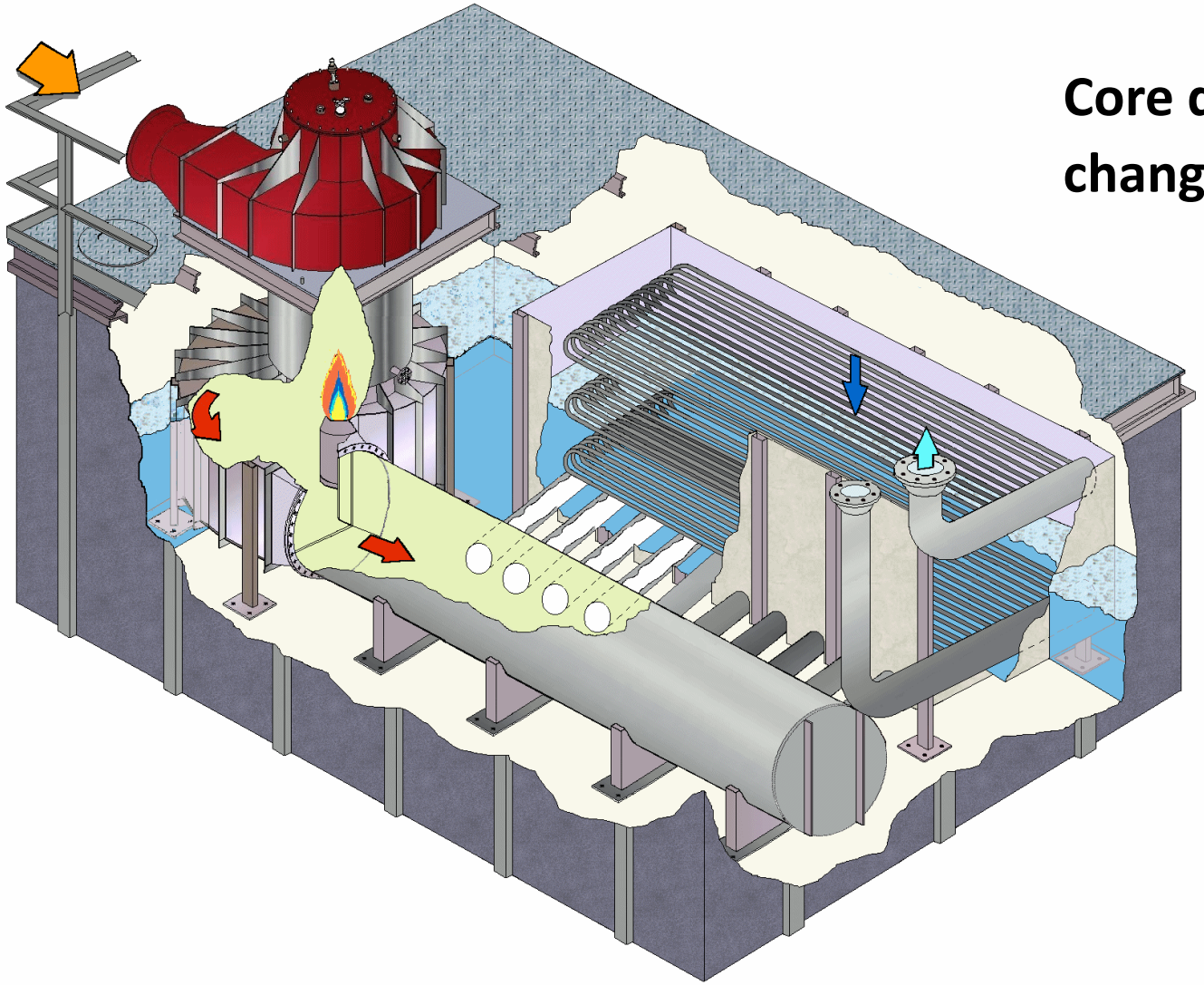



Ideal for mid to large size plants

# Vaporization Technologies

## Continuing to Tweak the Tried & True

**Vaporization Heat Transfer Technology**



**Core design has not changed over the years**

What's changed is the controls; easily obsolete in 10 years; disruptive innovation

## Cheap Shale Gas

### New Applications Are Driving this Market


# And What About All That Flaring?

## Another Application to Closely Track

# OPTI-LNG-M™ (5000-15000 gpd LNG)

## New Product Development

Virtual pipeline to the wellhead ◊ Think small scale ◊ Think distribution system

MODULAR SKID MOUNTED SMALL SCALE LOWER CAPEX EASIER TO MAINTAIN

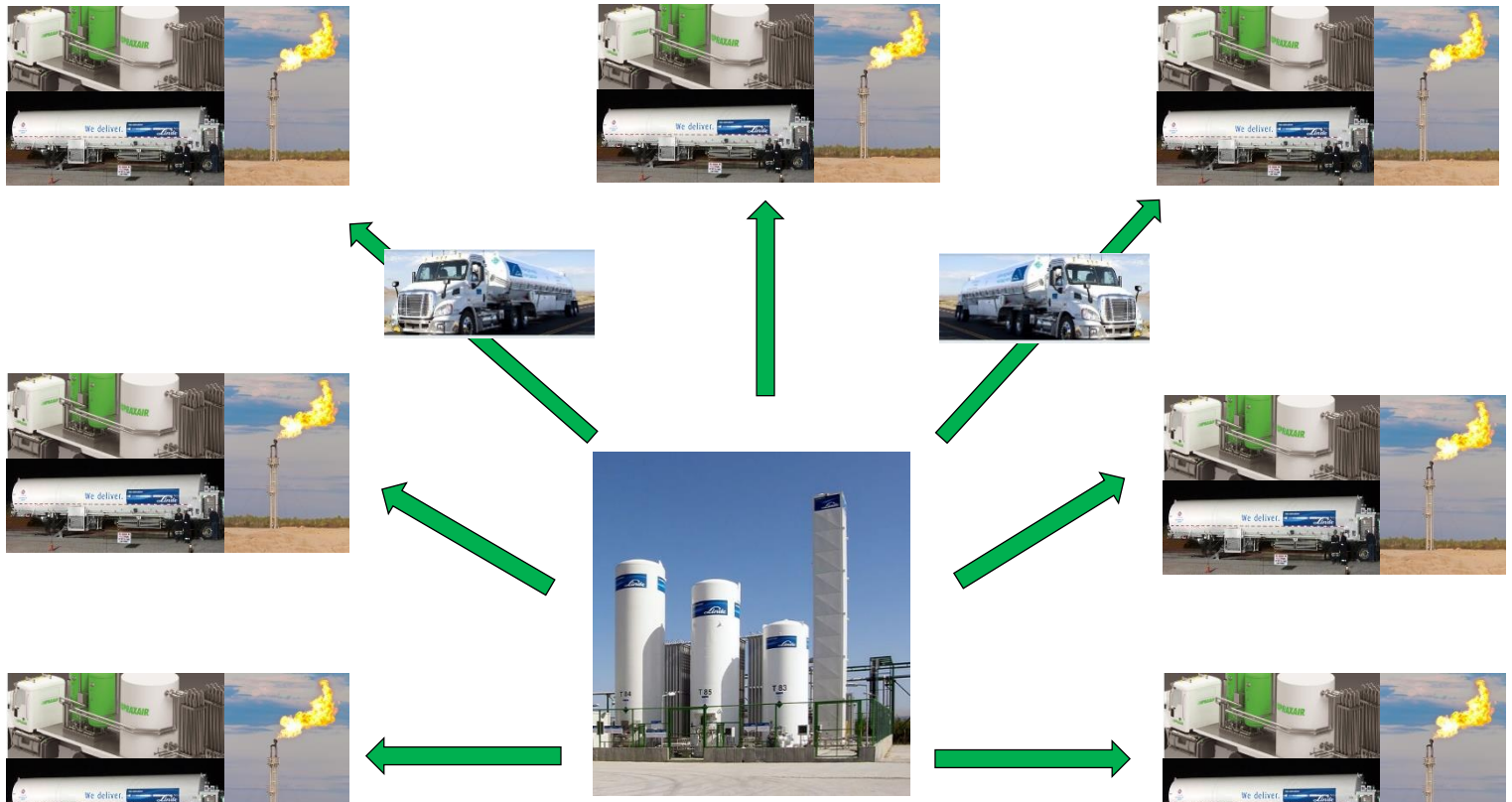

NEW APPLICATION OF LIQUID NITROGEN MORE ECONOMIC SOLUTION AS VIRTUAL PIPELINE

Flare gas pretreatment and liquefaction with liquid nitrogen

# Expanding the Flaring Solution to a Basin

## Hub & Spoke Model

## A different way to scale up



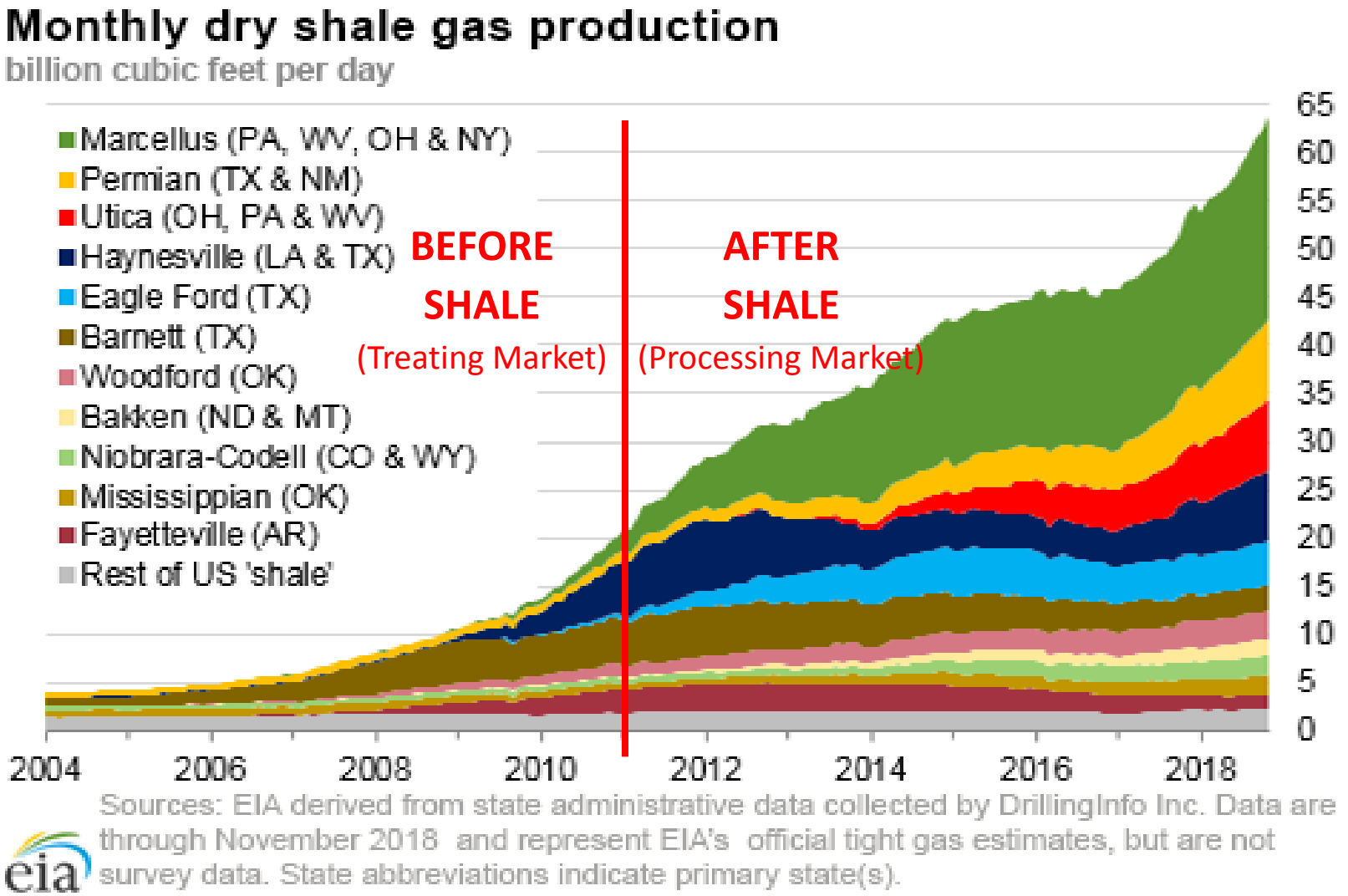
Liquid N2 plant or
co-production plant (LIN & LNG)

## Natural Gas Liquids (NGL)

### Impact to the NGL Industry: It's all About Speed-to-Market

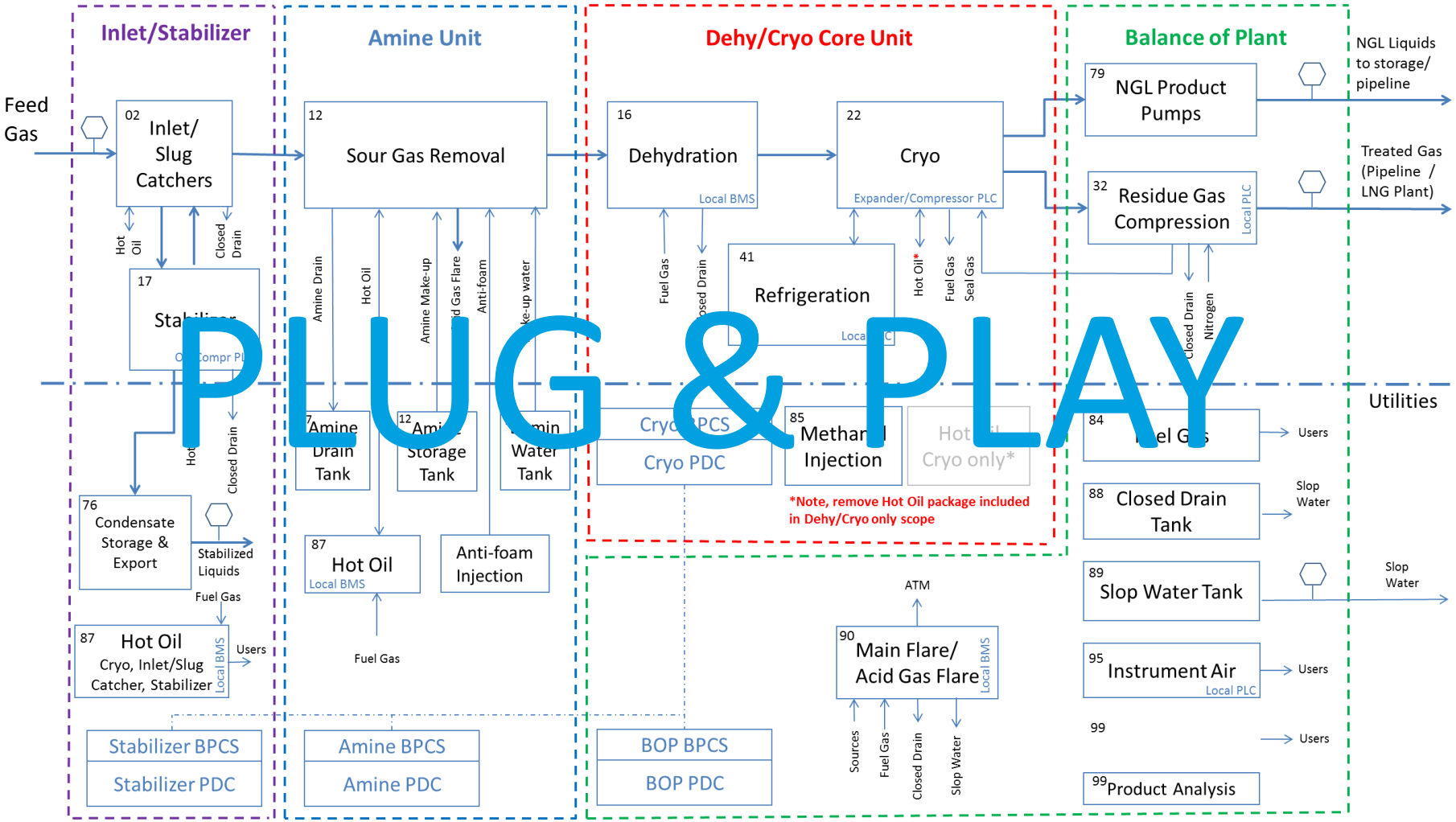
# Gas Processing

## The Before & After Look



# EPC Approach to Complete NGL Plant

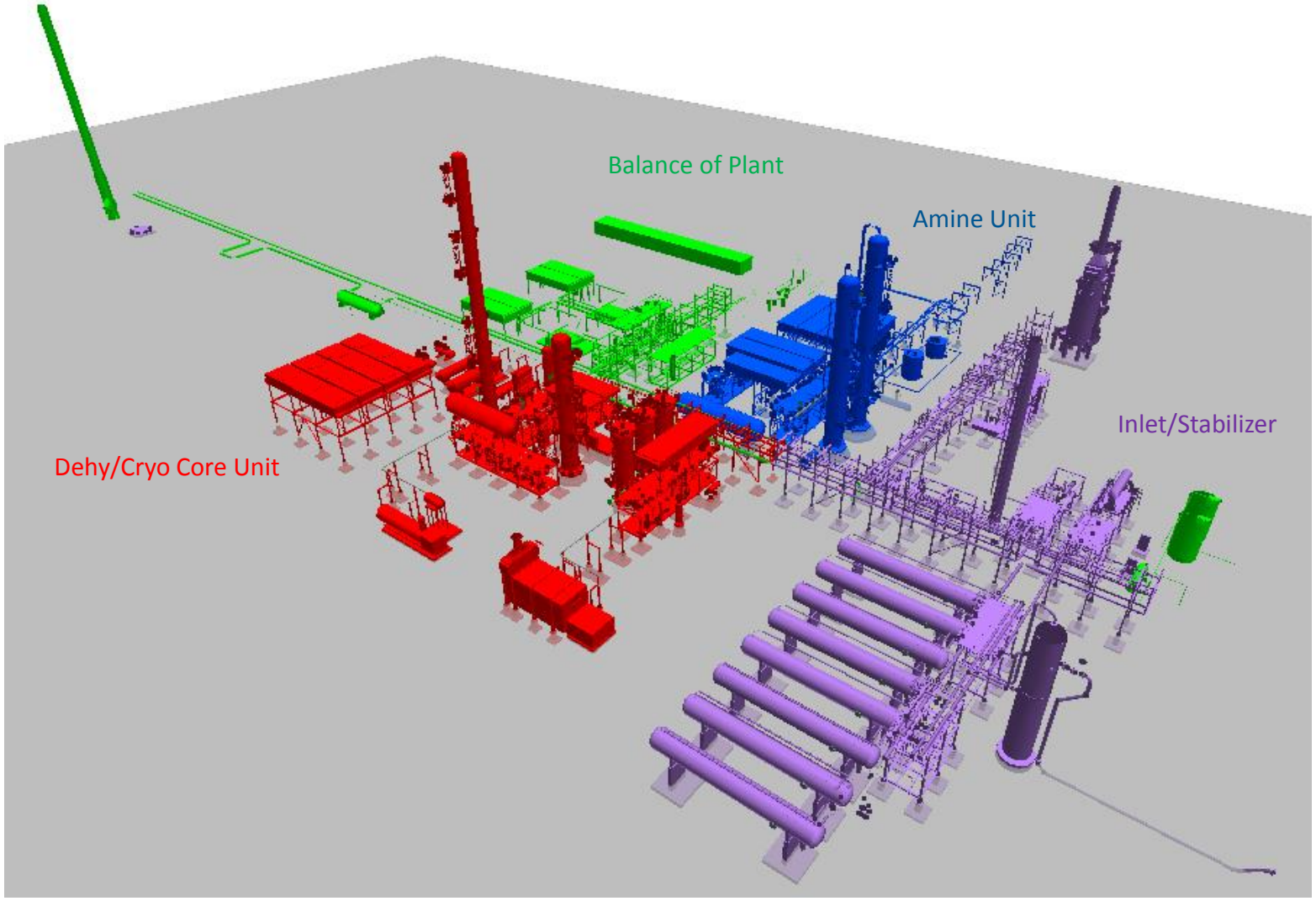
## Plug & Play



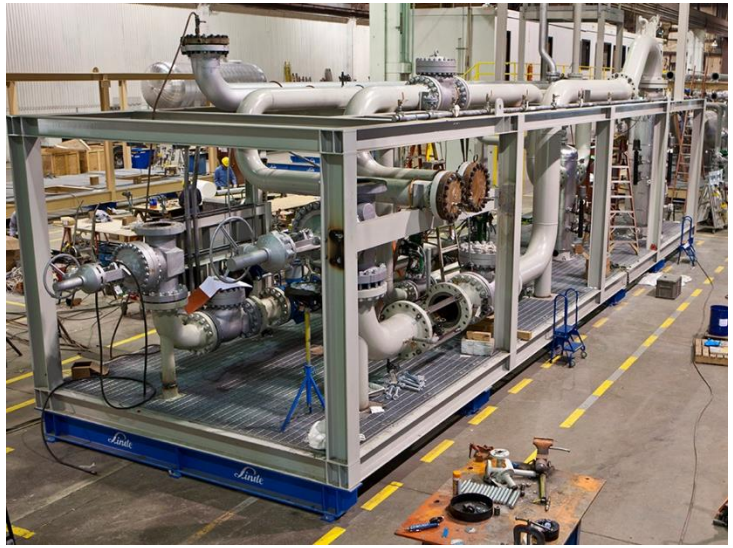
# NGL Plant - Plug and Play Offerings

## EPC or EP Approach

- Standardized
- Plug & Play
- Reduced cost
- Speed to market



# Standardization and Modularization Critical to Project Schedule



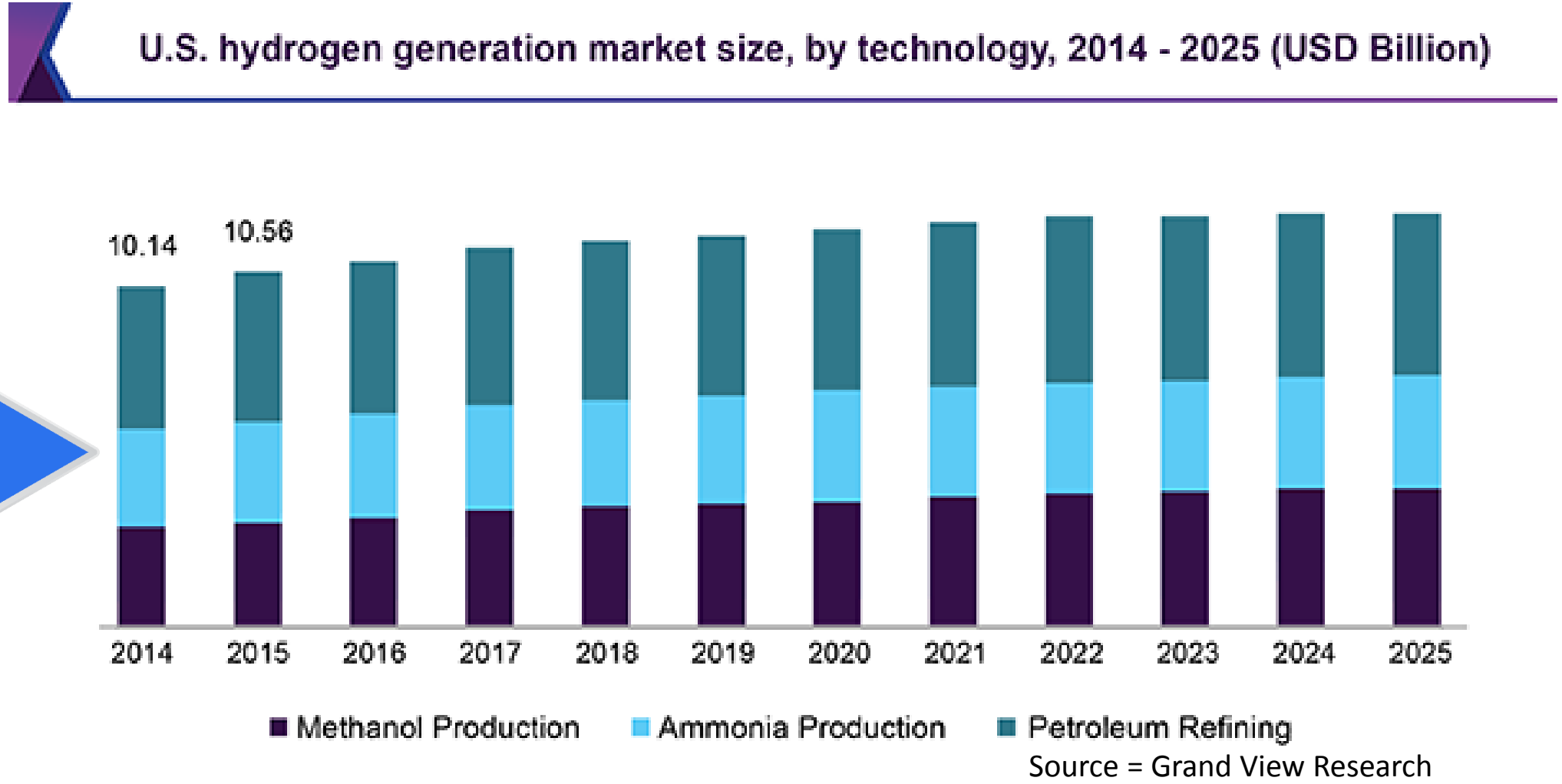

# Hydrogen

## Impact to the Refining Industry

# Growth in Hydrogen Production

## Where is all this Hydrogen Going?

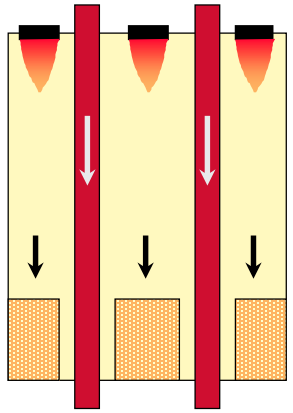
**CHEAP SHALE GAS**



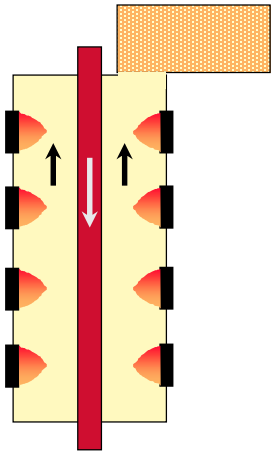

Source = Grand View Research

# Different Steam Reforming Options for Producing Hydrogen

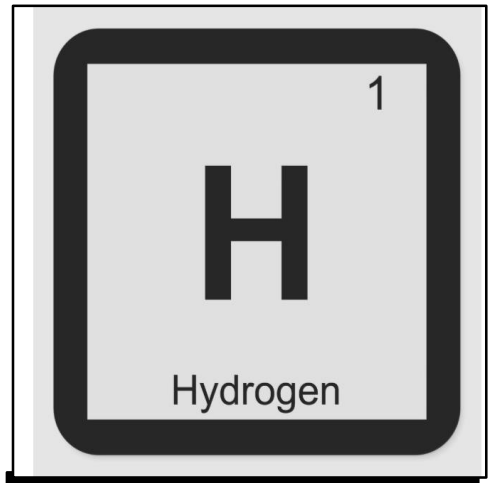
## Multiple Tubular Reformer Types

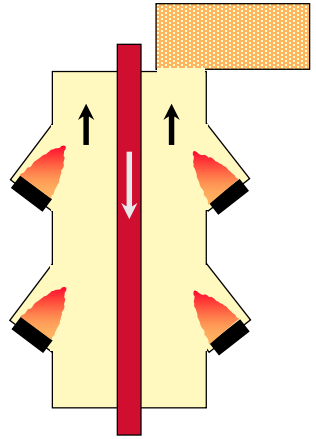
Top-Fired Reformer



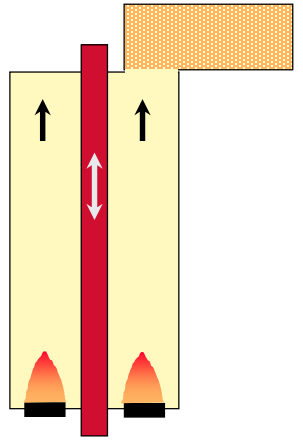
Side-Fired Reformer




Hydrogen is primarily produced by steam reforming of natural gas



Terraced-Wall Reformer



Bottom-Fired Reformer

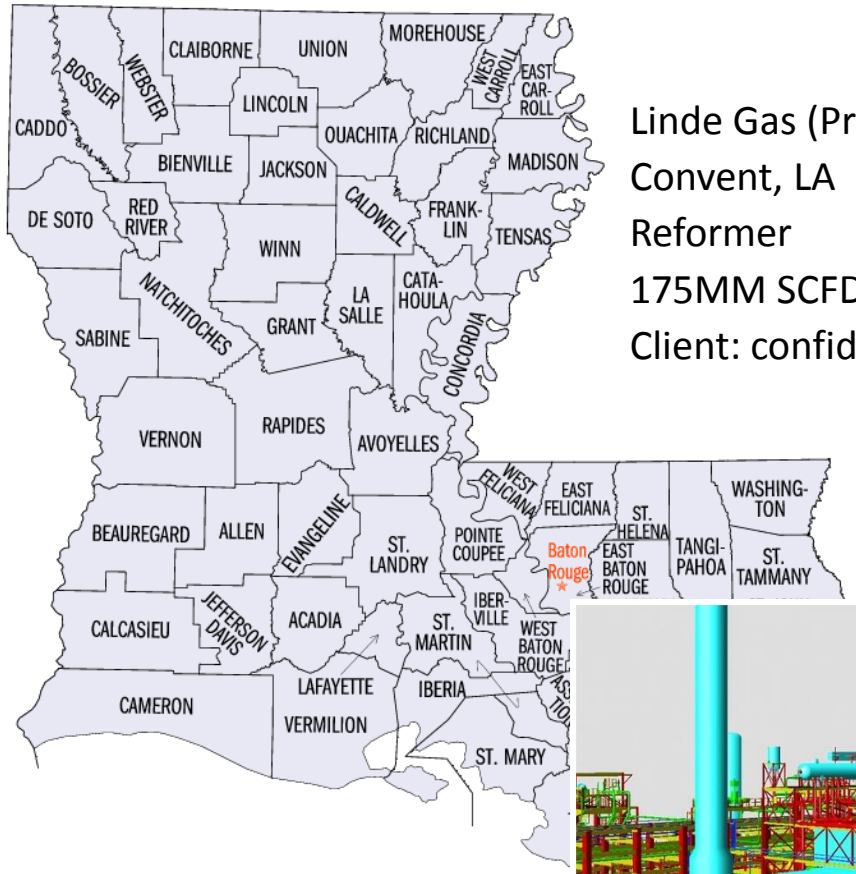
## Selas-Linde Top-Fired SMR Design Innovations

- Co-current Flow Design
- Inlet System Design
- Radiant System Design
- Outlet System Design
- Modular WHRU Design

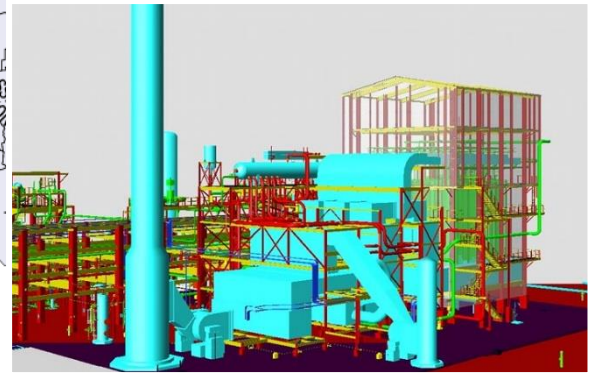
**BIG.....and getting bigger**

# Did I Say Bigger?

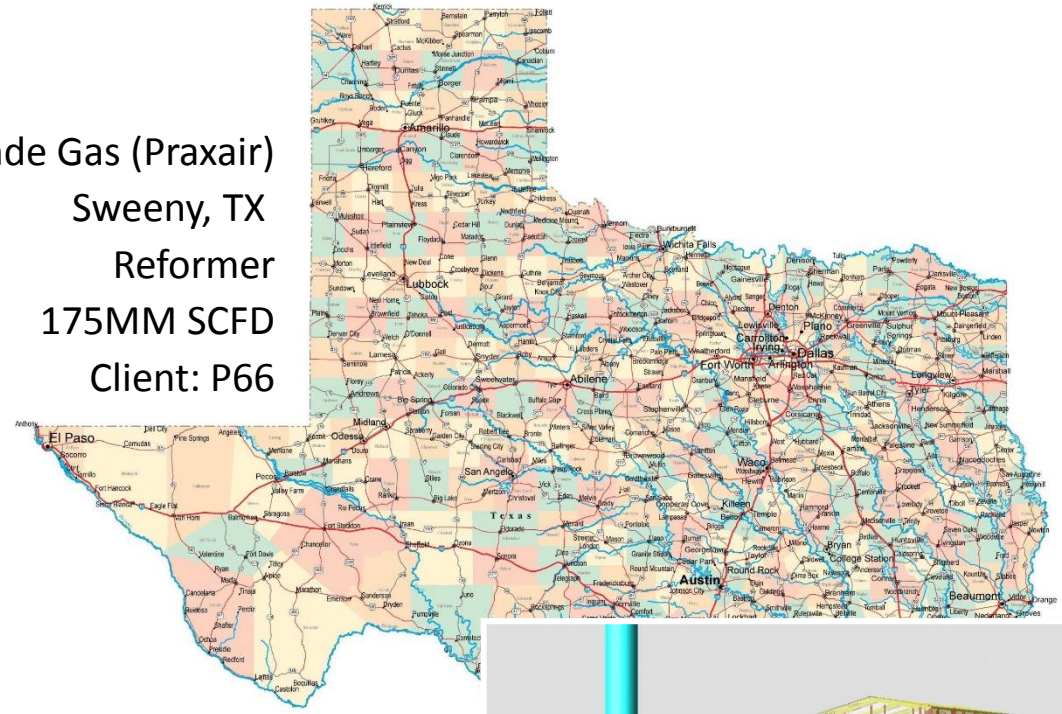
## Merchant Industry: Two New Hydrogen Supply Contracts / Plants

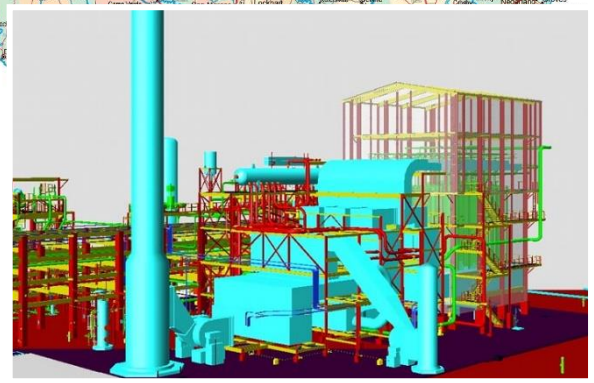



Linde Gas (Praxair)
Convent, LA
Reformer
175MM SCFD
Client: confidential



Linde Gas (Praxair)
Sweeny, TX
Reformer
175MM SCFD
Client: P66



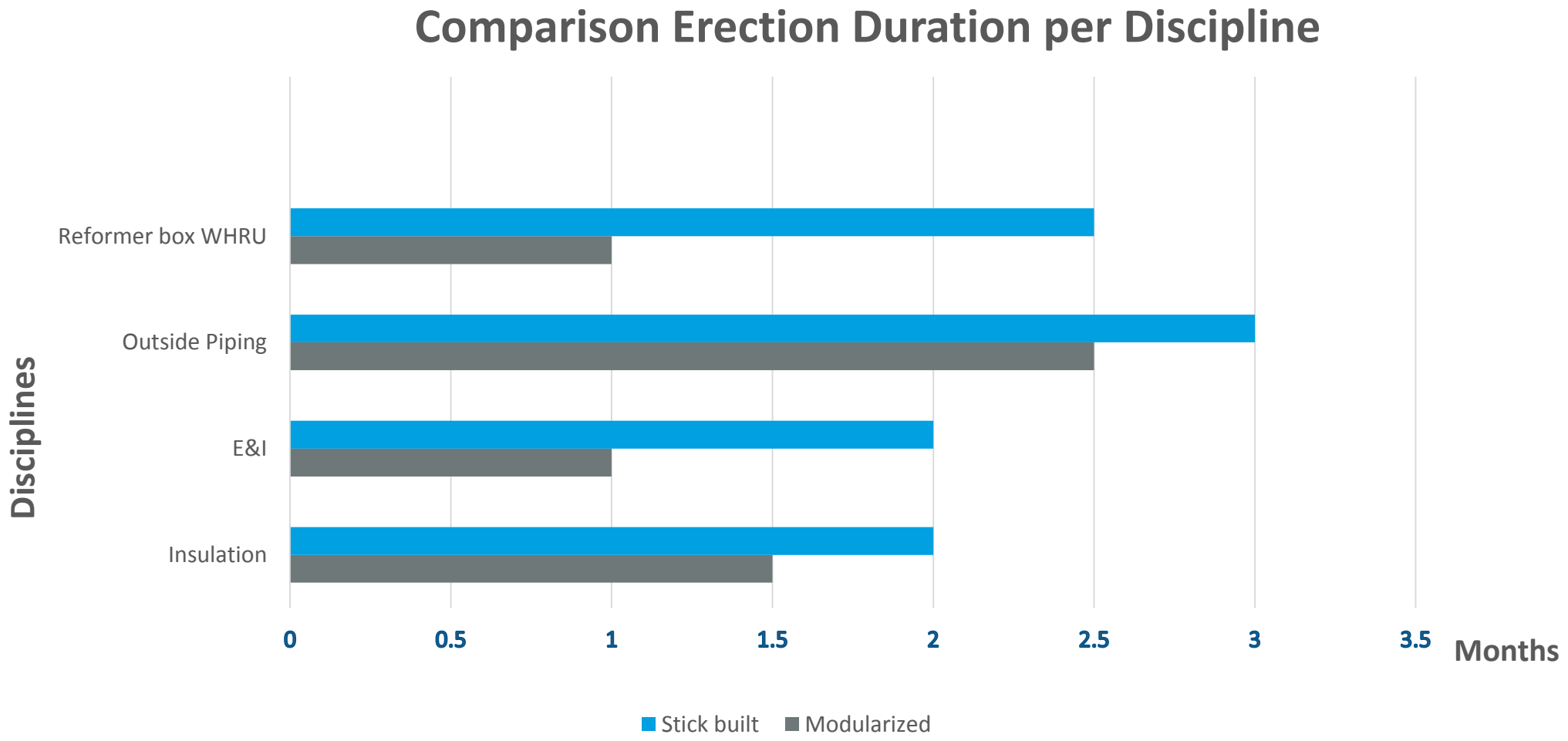
# Small Scale Plant Modularization

## Hydrogen & Ammonia



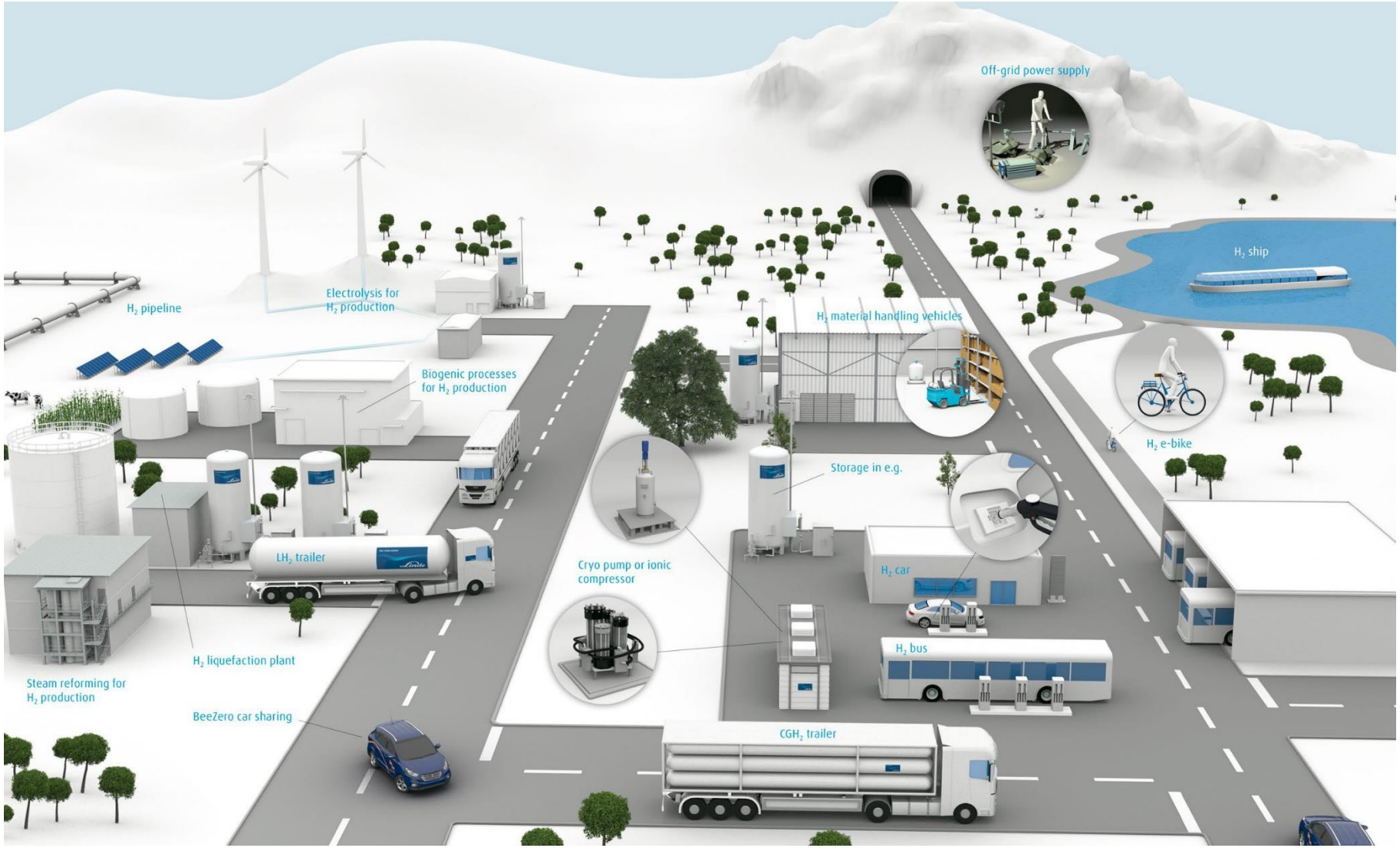

## Schedule Saving:

Modularized vs. Stick Built Reformer



# Increasing Use of $H_2$ as an Energy Carrier

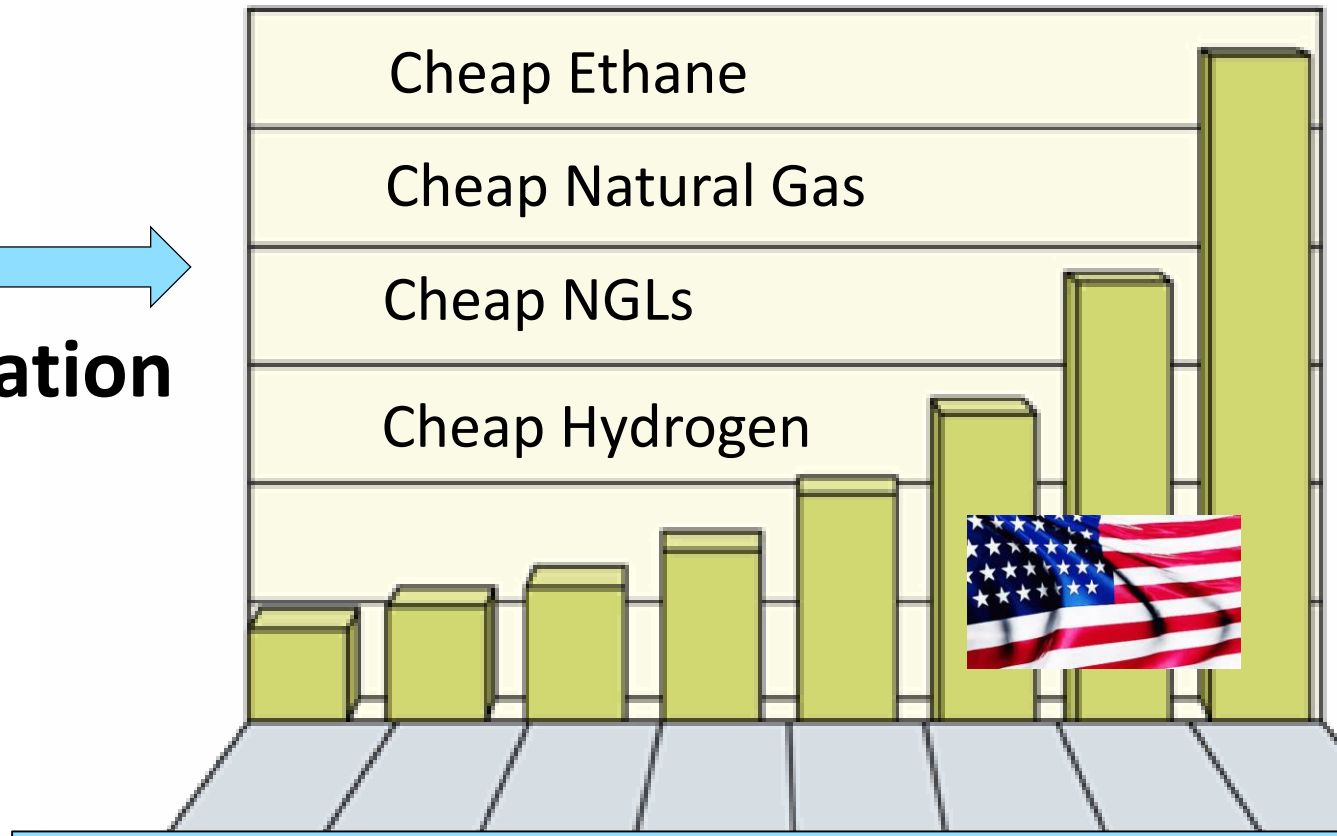
## Many New Opportunities in Mobility, Power & Heat



## For U.S. Producers

Nothing Short of an American Miracle

**The Great Energy Transformation**




**BIGGER, Modular Plants**

**UNPRECEDENTED Production & Profitability Increases**

Making our world more productive

# Thank you for your attention.

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