Presentation Outline

- Linde Overview & Role in Gasification Projects
- Expansion of Linde-operated NG-based complex in TX
- Reliance Gasification – World’s largest ASU & Rectisol units
- Rectisol Technology Advancements
- Key Learnings & Conclusions
The Linde Group Overview

- Founded: 1879
- Sales: ~$23 billion
- Employees: ~63,500
- Countries: >100

Leveraging Synergies

Linde Engineering
- Technology-focused
  - Air Separation
    - Global #1
  - Hydrogen/Syn Gas
    - Global #2
  - Olefins
    - Global #2
  - Natural Gas
    - Global #3

Linde Gas - Tonnage
- World-class operations
  - HyCO Tonnage Plants
    - >100 plants
  - ASU Tonnage Plants
    - >300 plants
  - CO2 Plants
    - >100 plants
  - ECOVAR Std Plants
    - >1,000 plants
Clean Coal Gasification Process and Downstream Products, Linde technology and product coverage

End Products

- H₂
- CO
- H₂/CO
- NH₃/Urea
- SNG
- MeOH/MTO
- CTL
- Power

Feasibility & Value Integration Studies

EPC

O&M & BOO
Significant ASU & Rectisol Activity Across the Globe
Selected recent activities

- > 75 Rectisol references w/ nearly all gasif. technology
- > 30 ASU’s for gasification projects in last 10 years
- Largest ASU scheme in operation – 30,000 tpd

- Owned & Operated by Linde
- EPC executed by Linde
- FEED/Integration Study by Linde

FEED/Integration Studies
EPC / Equipment Supply
O&M & BOO

HECA Rectisol
Dakota Gasification
Coffeyville ASU
La Porte Syngas
Shell Pearl
Reliance ASU/Rectisol/ SRU/PSA
Singapore Syngas
POSCO (Rectisol, SRU, SNG)

Clear Lake CO

Coffeyville ASU

Singapore Syngas

~30 Rectisol projects in last 10 yrs
~20 ASU in last 10 yrs
5 ASU BOO by Linde

Brisbane, Aus

Shell Pearl

Petcoke Gasif.

~30 Rectisol projects in last 10 yrs
~20 ASU in last 10 yrs
5 ASU BOO by Linde
Expansion of Linde Laporte, TX Facility
NG-based POx for petrochemicals

- $250mm investment by Linde: New gasification train, New ASU
- ASU on-line Dec 2014, Gasifier on-line Q1 2015
- World’s Largest NG-based gasification for petro-chemicals
- Owned & operated by Linde
Expansion of Linde Laporte, TX Facility
Advantages of NG-based POX for chemicals

- **Availability and Reliability** (> 99%) in the same range as NG fed SMR
- Favourable for overall **H₂/CO product ratio** below 3
- High syngas output possible - **up to approx. 500,000 Nm³/h H₂+CO** in a single line configuration
- **No catalyst** involved in the syngas generation
- **High syngas pressure** (>70 bar) feasible and proven, advantageous for downstream HP synthesis processes
- **Low CH₄ slip** (< 0.5%) and **low CO₂ by-production** (approx. 2% dry basis)
- **High pressure steam** production (>100 bar) feasible
- Operation with or without sulphur in the natural gas possible (syngas generation does not require upstream desulphurization)
- No steam adder to natural gas required (besides min. flow for purging), i.e. **S/C ratio near zero**
- **No soot formation** during normal operation
Reliance Petcoke Gasification
World’s largest ASU’s & Rectisol Plants

RIL Jamanagar Gasification Project
- Optimized polygeneration and cogen project for hydrogen & chemicals and to refuel & repower SEZ and DTA refineries
- AGR design is CO2 capture ready

<table>
<thead>
<tr>
<th>Package</th>
<th>Linde Scope</th>
<th>Licensor</th>
<th>Capacity</th>
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</thead>
<tbody>
<tr>
<td>ASU</td>
<td>EP</td>
<td>Linde</td>
<td>5,250 tpd O2 x 5</td>
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<tr>
<td>AGR</td>
<td>BE, DE, Proc’t Serv.</td>
<td>Linde</td>
<td>&gt;2,000,000 Nm³/h Raw syngas x 2</td>
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<tr>
<td>CWHE</td>
<td>EP</td>
<td>Linde</td>
<td>-</td>
</tr>
<tr>
<td>PSA</td>
<td>EP</td>
<td>Linde</td>
<td>&gt;300,000 Nm³/h H2</td>
</tr>
<tr>
<td>SRU</td>
<td>EP</td>
<td>WP</td>
<td>&gt; 1,000 tpd S x 4</td>
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<tr>
<td>SSH</td>
<td>EPC</td>
<td>Linde</td>
<td>-</td>
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Significant role of Linde
- Technology & EP contractor for many packages (highest order intake of overall project)
- Process integrator
The Target:
- supply oxygen at the lowest life cycle cost
- assure highest plant reliability

The Solution for Oxygen Supply:
- install five ASU trains
- capacity of each train - 5250 tpd oxygen (largest plant size worldwide)
- highest power efficiency

**Main Air Compressor** 28 MW
**Booster Air Compressor** 12 MW
**Total Power per train** 40 MW

**Driver:** Steam Turbine
**Steam Pressure:** > 100 bar
**Supplier:** Siemens
Reliance Petcoke Gasification
ASU - Equipment Shipment

Aluminum Columns

Distributor Installation – China shop
Reliance Petcoke Gasification
World’s largest Rectisol® Plants (2 identical plants)

Dimension (each): 410 x 110 m
Equipment # (each): ~ 215
Coil Wound HE (each) - 10
Tallest column: ~ 125 m
Heaviest column: ~ 1600 MT

Piping tonnage (each): ~12,000 MT
Concrete volume (each): ~ 66,000 m³
Steel tonnage (each): ~12000 MT
Average pipe size: 14"
Reliance Petcoke Gasification
World's largest Sulphur Recovery Plants with O$_2$ enrichment process (4 identical trains)

Dimension (each train): 146 x 95 m  
Equipment: 364  
Tallest column: ~28 m  
Heaviest equipment: ~250 MT  

Piping tonnage: 9,000 MT  
Concrete volume: 54,400 m$^3$  
Steel tonnage: 5,300 MT  
Average pipe size: 8"
### Reliance Petcoke Gasification

World's largest Product Capacity PSA Plant for H2 Purification

<table>
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<tr>
<th>Description</th>
<th>Value</th>
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<tr>
<td>Product Capacity</td>
<td>301,885 Nm3/h</td>
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<tr>
<td>Dimension</td>
<td>44 x 18 m</td>
</tr>
<tr>
<td>Equipment</td>
<td>14 + 1</td>
</tr>
<tr>
<td>Tallest Vessel</td>
<td>~50 m</td>
</tr>
<tr>
<td>Heaviest equipment</td>
<td>~160 MT</td>
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</table>
Rectisol Technology Developments
Linde’s Rectisol test center and recent advancements

Location: Singapore
Start-up: April 2012

Feed-Gas:
Side-stream from Linde Gas Singapore plant. Syngas generated by POX gasification of heavy residue oil (degassed Visbreaker residue)

Pilot Plant:
Feed Gas Capacity: 150 Nm³/h

Test conditions in a real syngas atmosphere under pressure
Results – Key Components (CO2 and H2S)
Measuring campaign at various operating points for comprehensive data basis (e.g. variation of feed gas flow and pressure, variation of solvent flow and temperature, variation of CO2 content in feed gas)

Improved property database leading to reduced solvent flowrates (OPEX)
Improved equipment design basis leading to reduced column heights (CAPEX)

Results – Trace Components

<table>
<thead>
<tr>
<th>Component</th>
<th>Comment</th>
<th>syngas purity</th>
</tr>
</thead>
<tbody>
<tr>
<td>COS</td>
<td>Good solubility confirmed – no upstream hydrolysis required</td>
<td>&lt; 0.1 ppmv (H2S+COS)</td>
</tr>
<tr>
<td>HCN</td>
<td>Good solubility confirmed – no enrichment in solvent</td>
<td>&lt; 0.1 ppmv</td>
</tr>
<tr>
<td>Carbonyls</td>
<td>Design basis improved</td>
<td>&lt; 0.1 ppmv</td>
</tr>
<tr>
<td>Hg</td>
<td>Design basis improved</td>
<td>Not detectable</td>
</tr>
</tbody>
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In Closing…..

- Linde is a technology-driven EPC contractor with significant gasification experience including FEED, EPC, and BOO

- Linde owns wide range of technologies for gas cleaning, conditioning & purification and is open to partner with several technology providers where required

- Optimized process integration is often key to success, especially in poly-generation projects

- Gasification/POX has a role in US shale-gas expansion

- Capacity limits for ASU & Rectisol plants continue to be pushed to further improve gasification project economics
Thank you.