State of the Art Ammonia Plants and Global Project Execution Capabilities

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THE LINDE GROUP

Linde

Gases Division

Who are We?

THE LINDE GROUP

Engineering Division

Business review

Growth in revenue and operating profit

- Group revenue increased to EUR 17.9 bn
- Group operating profit increased to EUR 4.1 bn
- Operating cash flow increased to EUR 3.6 bn
- 9.5 percent rise in dividend to EUR 3.45 per share

3

Integrated Gases and Engineering model

Synergies built on strong engineering foundation

THE LINDE GROUP

Gases Division

2015 Sales: EUR 15.2bn

Optimised CAPEX and OPEX for own assets

Strong competitive position

Solution provider for the customer

Synergies

Risk balancing

— Capture business either as plant sales or outsourcing contracts

— Awareness of decaptivation opportunities

Customer

— Early awareness of new projects

— Strong customer relationships

Operations

— Long track record of executing large-scale projects

— High cost competitive-ness and energy efficiency

Innovation

— Improvement of applications and solutions

— Insights into cus-tomer processes

Engineering Division

2015 Sales: EUR 2.6bn

Technology leadership geared towards leveraging expertise into Gases business

Four technology fields (Air Separation | Hydrogen & Syngas | Natural Gas | Petrochemicals)

4

Gases Division

Wide range of products, services and applications

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Gases

Air Gases
- Nitrogen (N_2)
- Oxygen (O_2)
- Argon (Ar)
- Rare Gases
  Krypton (Kr)
  Neon (Ne)
  Xenon (Xe)

Other Gases
- Acetylene (C_2H_2)
- Helium (He)
- Propane (C_3H_8)
- Carbon Dioxide (CO_2)
- Carbon Monoxide (CO)
- Hydrogen (H_2)

Specialty Gases
- Pure Gases
- Specialty Gas Mixtures

Medical Gases
- Medical Oxygen
- Nitric Oxide (NO)
- Nitrous Oxide (N_2O)

Services

Administrative Efficiency

Process Know-how

Quality and Safety

Supply Reliability

Applications

Healthcare

Chemistry & Energy

Metallurgy & Glass

Manu-facturing

Retail

Food & Beverages

Electronics

Other

Linde gases are used, for example, in the energy sector, steel production, chemical processing, environmental protection and metal fabrication, as well as in glass production, food processing and electronics. The company is also a leading global supplier of premium healthcare products and services for patients with respiratory disorders.

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Engineering Division

Leading market position in multiple segments

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Air Separation Plants	Hydrogen and Synthesis Gas Plants	Petrochemical Plants	Natural Gas Plants
			

Providing plants for Linde Gas and third party customers

Providing plants for chemical industry and energy-related industries

With around **1,000 process engineering patents and applications** and about **4,000 completed plant projects,** Linde Engineering supports the energy and environment megatrend and leverages customer relationships for gas projects.

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Linde Engineering
T-EPC Solution Provider

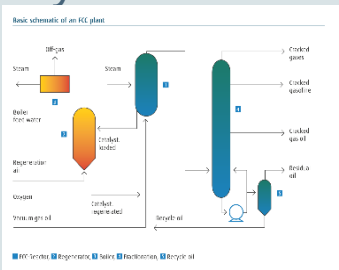
THE LINDE GROUP

We manage the full project lifecycle.

TEPC

We are your one-stop-shop for process plant execution.

Technology



Engineering

Procurement

Construction

Efficient organisation	Clearly structured processes	Competence in execution	4000+ convincing arguments

Agenda.

1. The Linde Ammonia Concept (LAC)™
2. Standardized and Modularized Plants
3. Modularization
4. Project Execution today

TECHNOLOGY

TECHNICAL CONCEPT

ABILITY TO EXECUTE

THE KEY TO COST EFFECTIVE AND COMPETITIVE (SMALL SCALE) AMMONIA PLANTS

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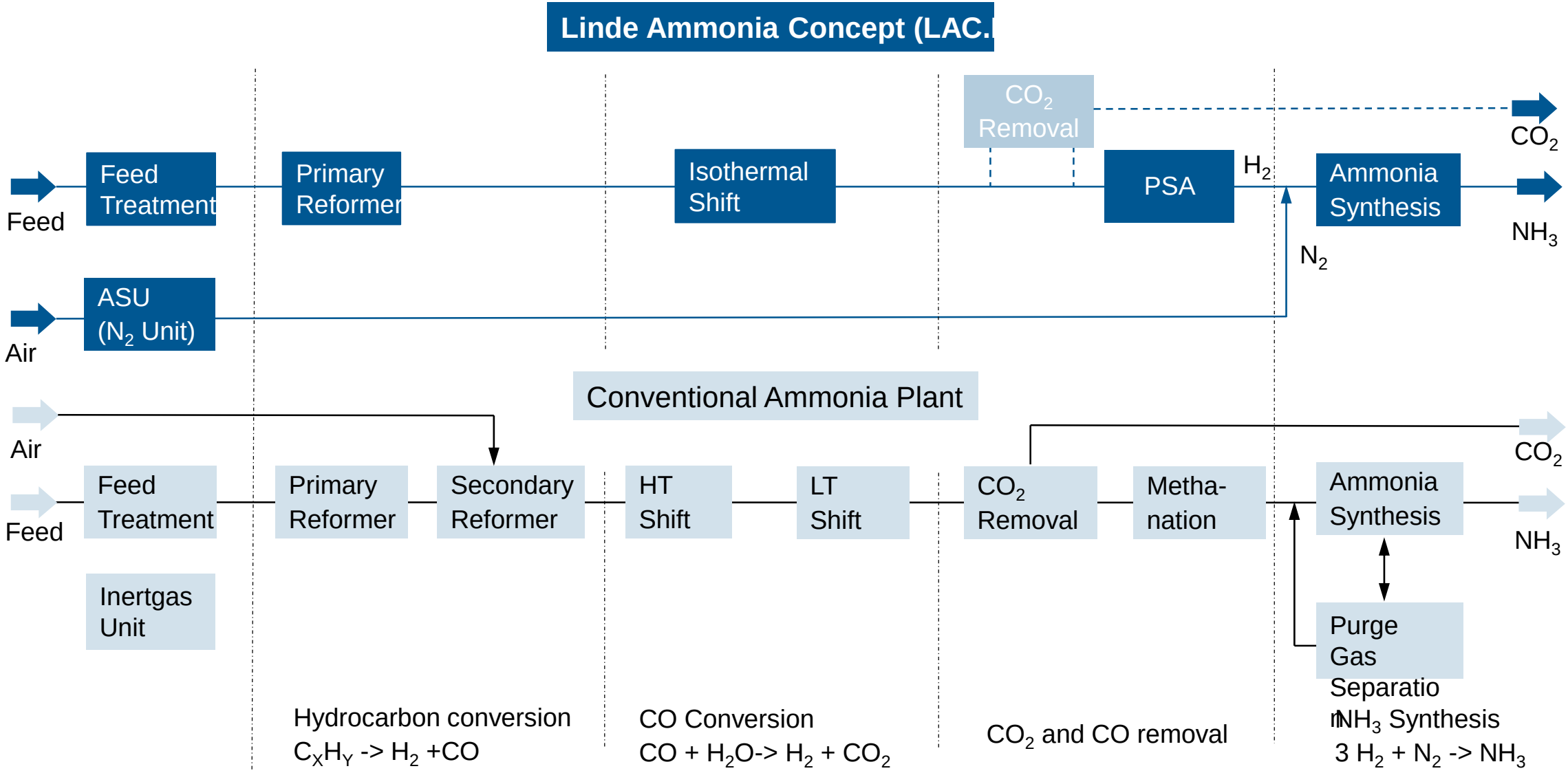
Linde Ammonia Concepts

Comparison of LAC.L1 process with conventional scheme



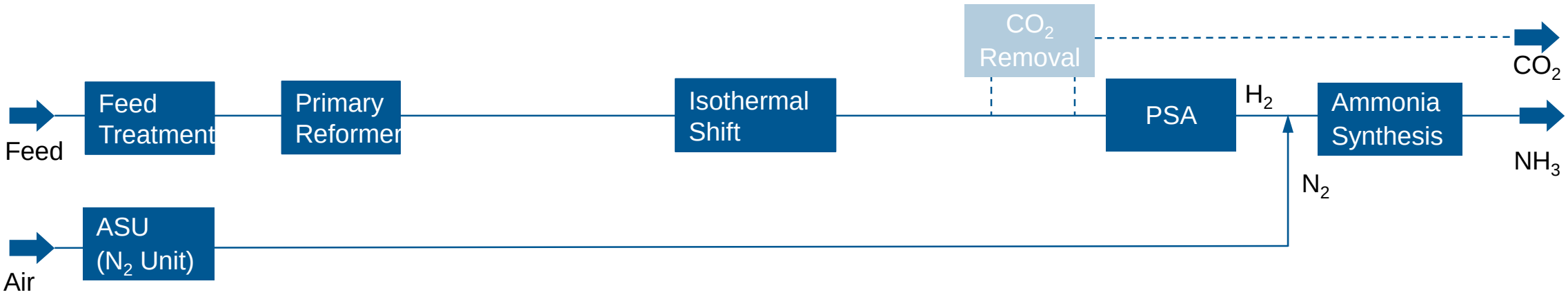
Linde Ammonia Concepts (LAC)
Characteristics

– Generation of an **inert-free** Ammonia **synthesis gas** in the right H_2 to N_2 ratio

– **Adjustable CO_2/NH_3** Product Ratios

– Design **Feedstock flexibility** from Light Hydrocarbon Feedstocks (LAC.L) to Heavy Hydrocarbon Feedstocks (LAC.H)

– Flexibility for **valuable by-products**, extension, and integration



Linde Ammonia Concept (LAC.L1)

Flexibility in plant design and operational Reliability

– **CO_2-Removal is eliminated for pure NH_3 production**
If CO_2 is needed, size of CO_2-Removal is adjusted according to CO_2-demand
CO_2-Removal can be integrated at a later stage with no pre-investment

– **Pure Hydrogen and pure Nitrogen** are directly available from process streams
Other potential by-products such as oxygen, argon, carbon monoxide, carbon dioxide and methanol can be easily integrated

– **High Flexibility with regard to steam and driver concepts** allows perfect integration into existing sites or downstream units
Process Steam System is separated from export and driver steam system

– Provision of a sophisticated **gas purification system by Pressure Swing Adsorption (PSA)**, which has proven and unmatched reliability and even allows NH3 production without shift conversion in operation

Linde Ammonia Concept (LAC.L1)

Cost and Energy savings

– **Elimination of three catalytic process steps**, reducing the total catalyst volume to appr. 50% of that in a conventional plant

– **N_2 is added at the back end** of the process leading to smaller and more efficient syngas cooling

– The generation of an **oxygen and inert free synthesis gas**, giving important **savings in the synthesis loop** and eliminates a purge gas purification step

– The process **condensate treatment is eliminated** by routing the process condensate directly to the isothermal shift reactor for the production of process steam

– The simplified flow sheet also results in a **reduced pressure drop**

– **The LAC is a much more direct route to ammonia resulting in a reduced start-up time and important savings in lifecycle costs**

Linde Ammonia Concept (LAC.L1)

Summary

Overall simplification of the classical process route, resulting in

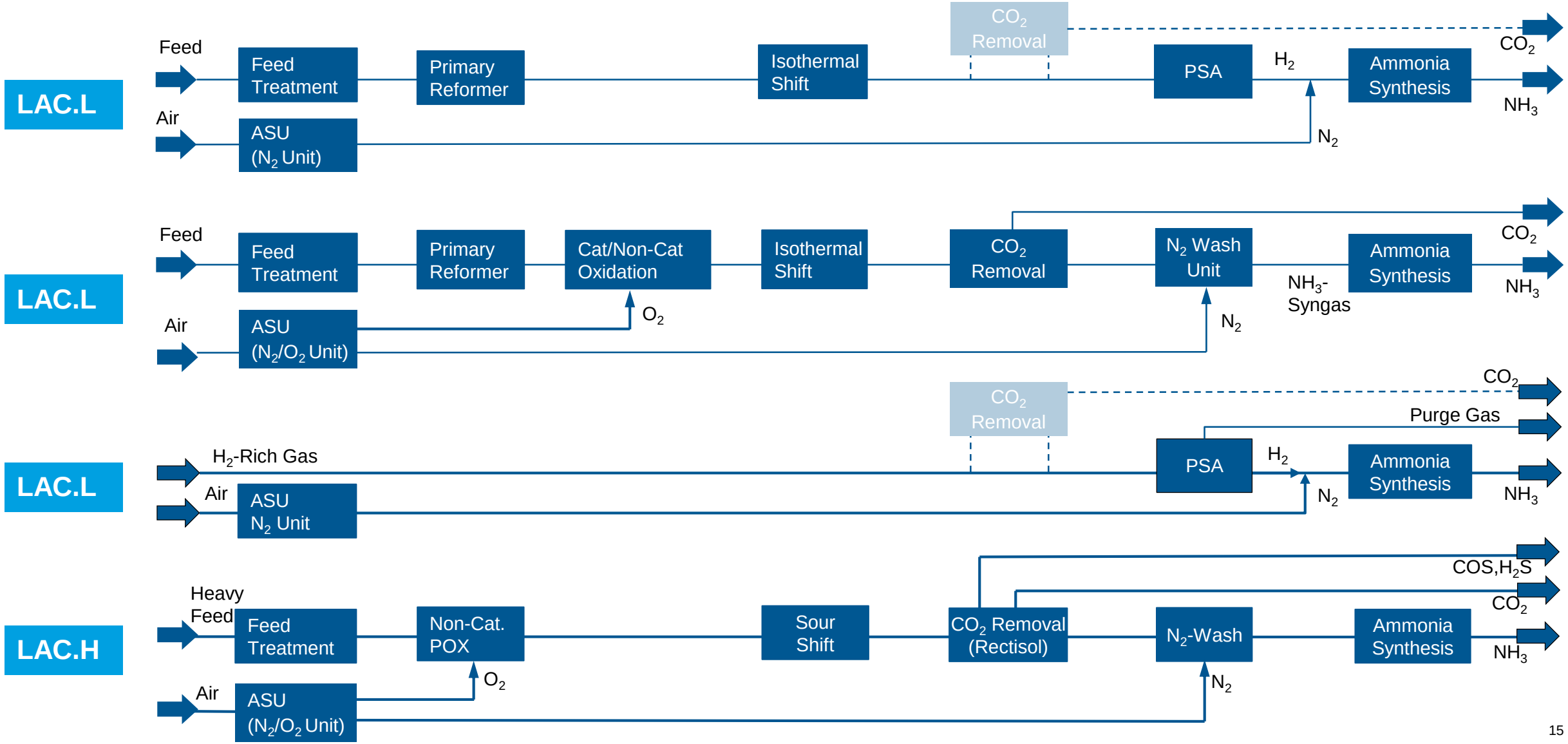
– **Savings** in investment, catalyst replacement and spare part costs, construction time, site area, maintenance

– **Flexibility** for extension and integration

– **Reliability** increase

Linde Ammonia Concepts (LAC)

Overview



Linde Ammonia Concepts (LAC)

A combination of proven Technologies

Linde Owned Technologies

Air Separation

Reforming Technologies

Rectisol Wash unit

Pressure Swing Adsorption

Isothermal Shift Conversion

Catalytic Oxidation

Nitrogen Wash Units

Linde Ammonia Concepts (LAC)

A combination of proven Technologies

Licensed Technologies/Equipment

Partial Oxidation/ Non-Catalytic Oxidation

Activated amine based CO_2 removal system

Ammonia Synthesis Converter

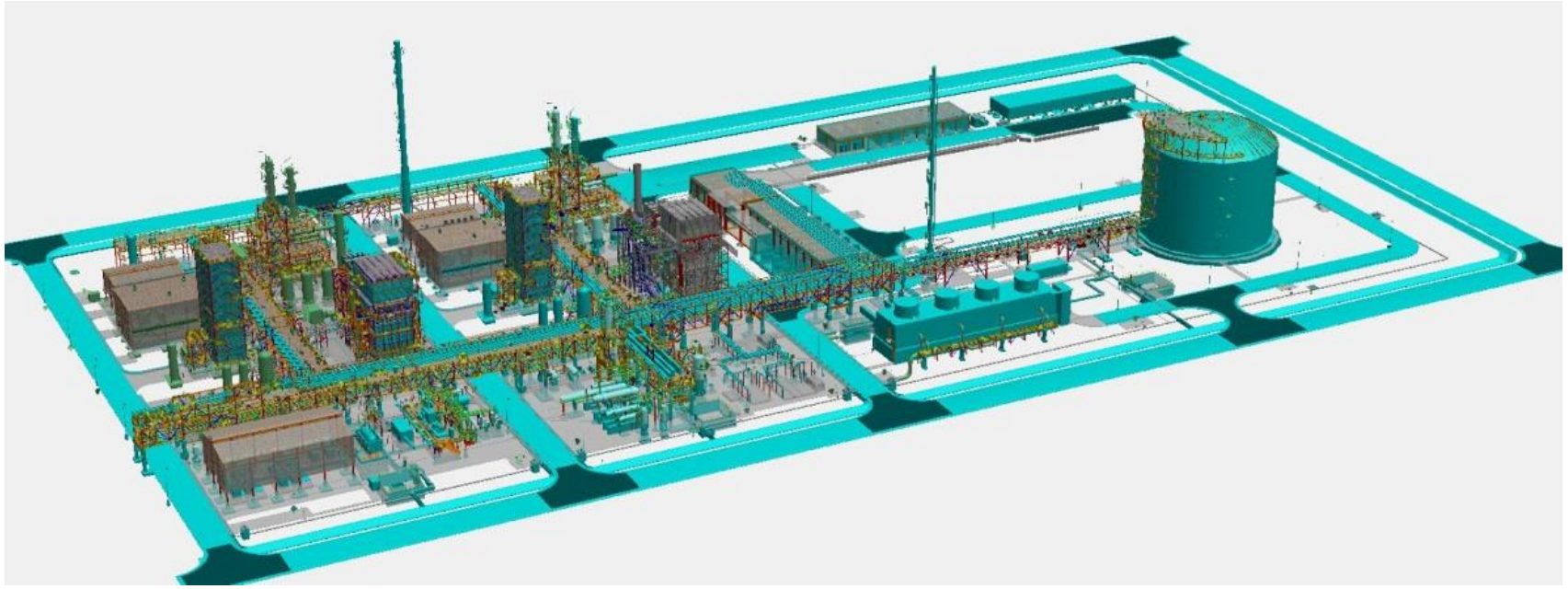
Linde's recent Experience in LAC.L Projects:
HyCO + NH_3 Plant for the Sadara Complex

Linde's largest HyCO facility and first NH_3 supply scheme in the Middle East
Products supplied to Sadara Chemicals Company LLC (Saudi Aramco/Dow JV)

Technology
– 2 x 65% SMR HyCO trains
– 1 x Ammonia Loop
– 20kt storage tank

Capacity
– Syngas: ~ 130,000 Nm3/h
– CO: ~ 21,320 Nm3/h
– H_2: ~ 91,000 Nm3/h
– NH_3: ~ 615 tpd

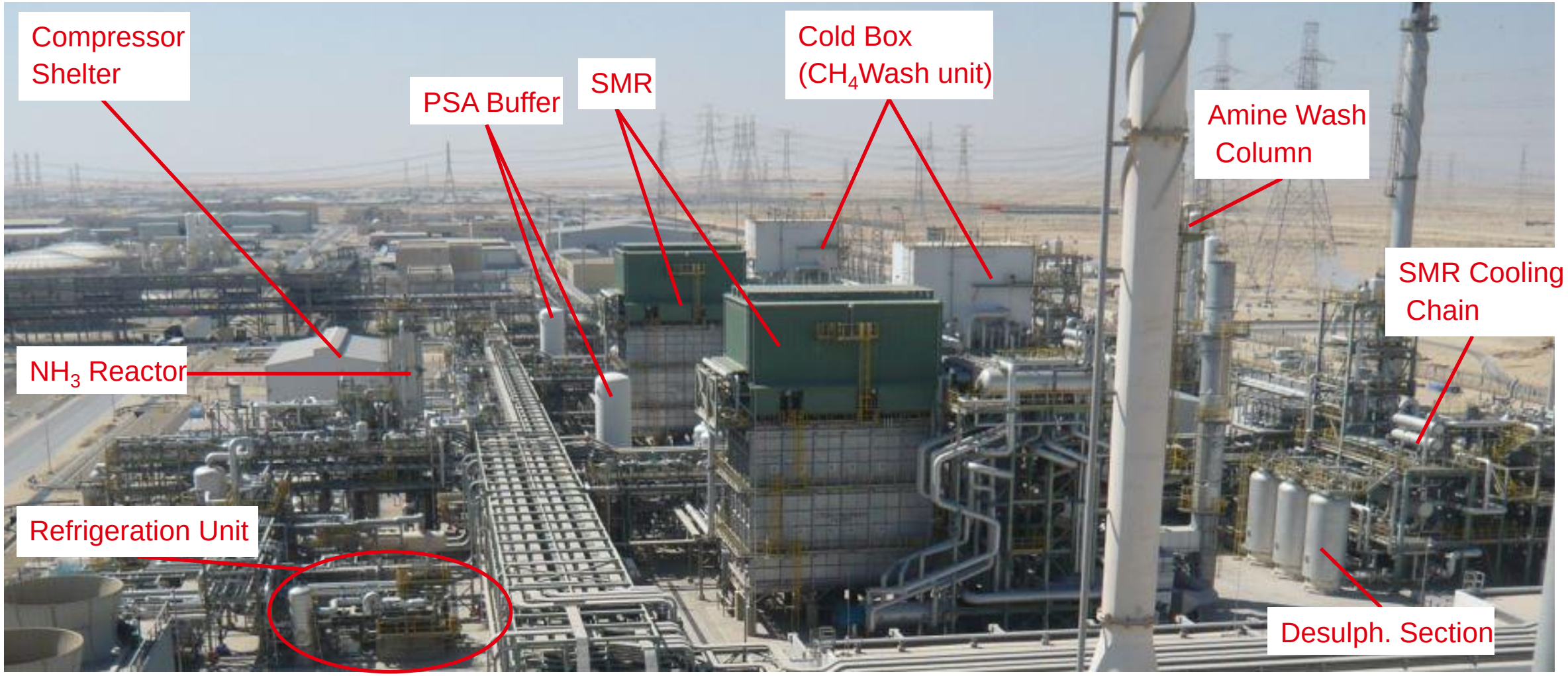
Feedstock
– Natural gas



Design and EPC of the plant executed by Linde Engineering
Facility owned and operated by Linde with successful start up in first half of 2016

Linde's recent Experience in LAC.L Projects:

HyCO + NH_3 Plant for the Sadara Complex



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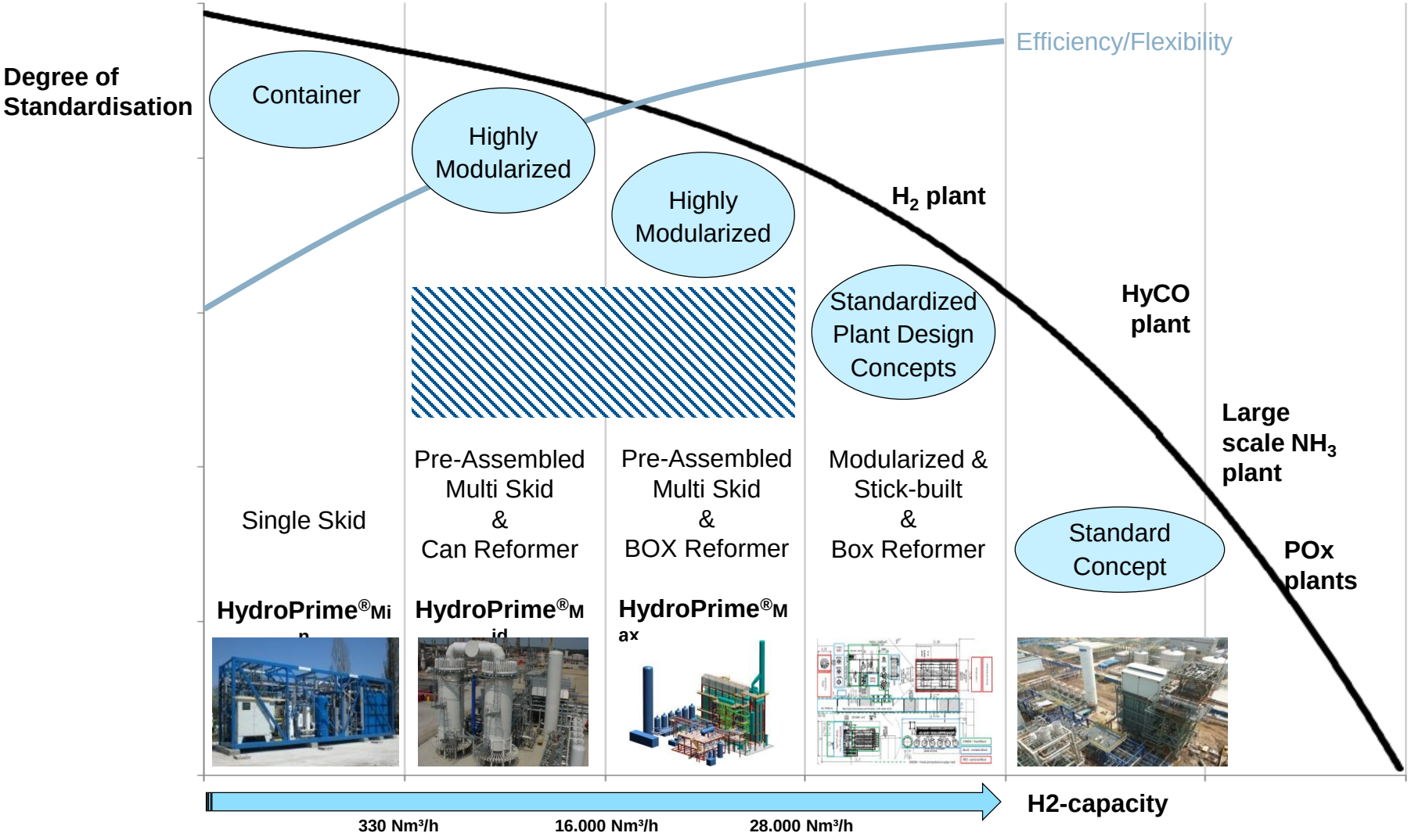
LINDE´s Standardized and Modularized (Hydrogen) Plant Portfolio



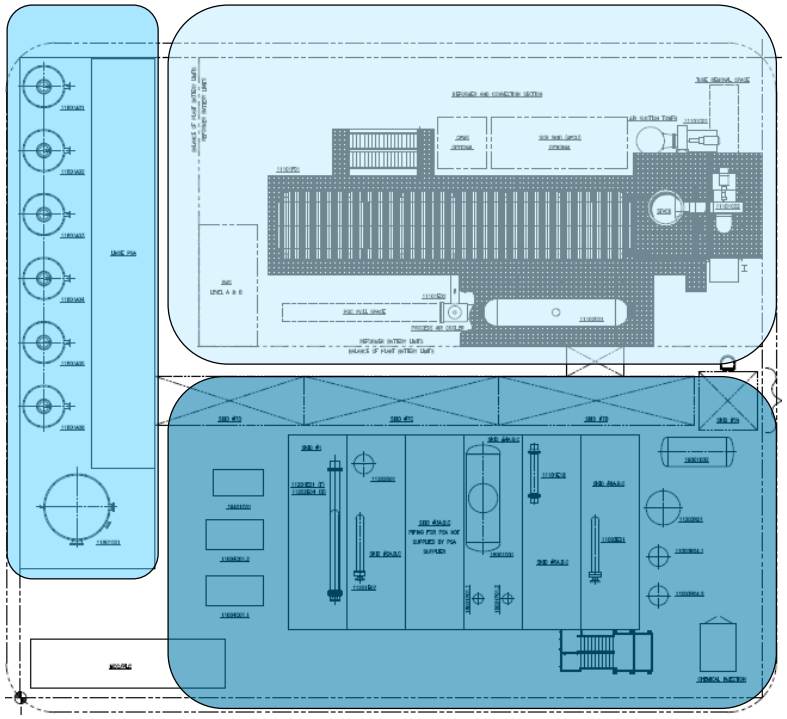
Range for
150 MTPD – 350 MTPD
NH3 plants based on the
Linde **A**mmonia **C**oncept
(LAC™)

Modularized plant concepts „HydroPrime® MID/MAX“ .

CAPEX/OPEX
optimized PSA

Can or Box Reformer

Design of all
Key-Equipments
is based on well proven
Technology from LINDE



Balance
of the Plant

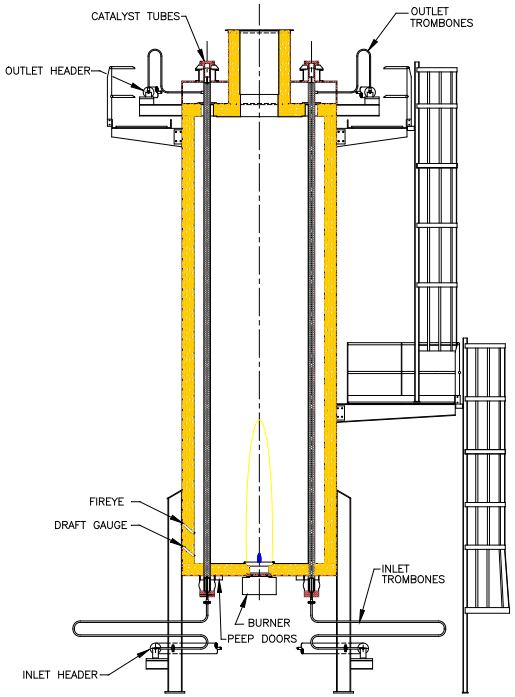
Modularized plant concepts.

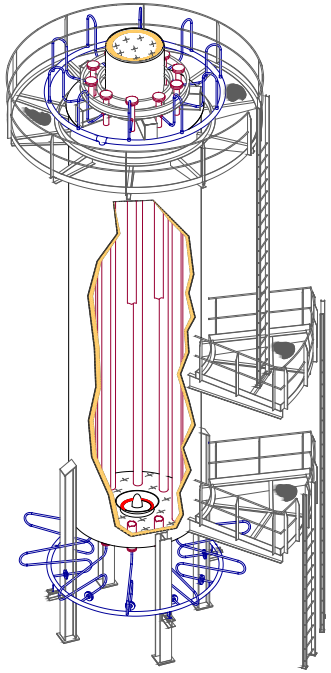
Can reformer plants “HydroPrime MID”.

H2-Capacity:

650 to 8.000 Nm³/h single can reformer

8.000 to 17.000 Nm3/h twin can & single WHRU





Can Reformer Design:

→ UP – FIRED

→ UP – FLOW

— easy access to burner

— easy maintenance (refilling)

— easy control

— low investment cost

Modularized plant concepts.
Box reformer plants “HydroPrime MAX”.

H2-Capacity:
16.000 to 28.000 Nm³/h

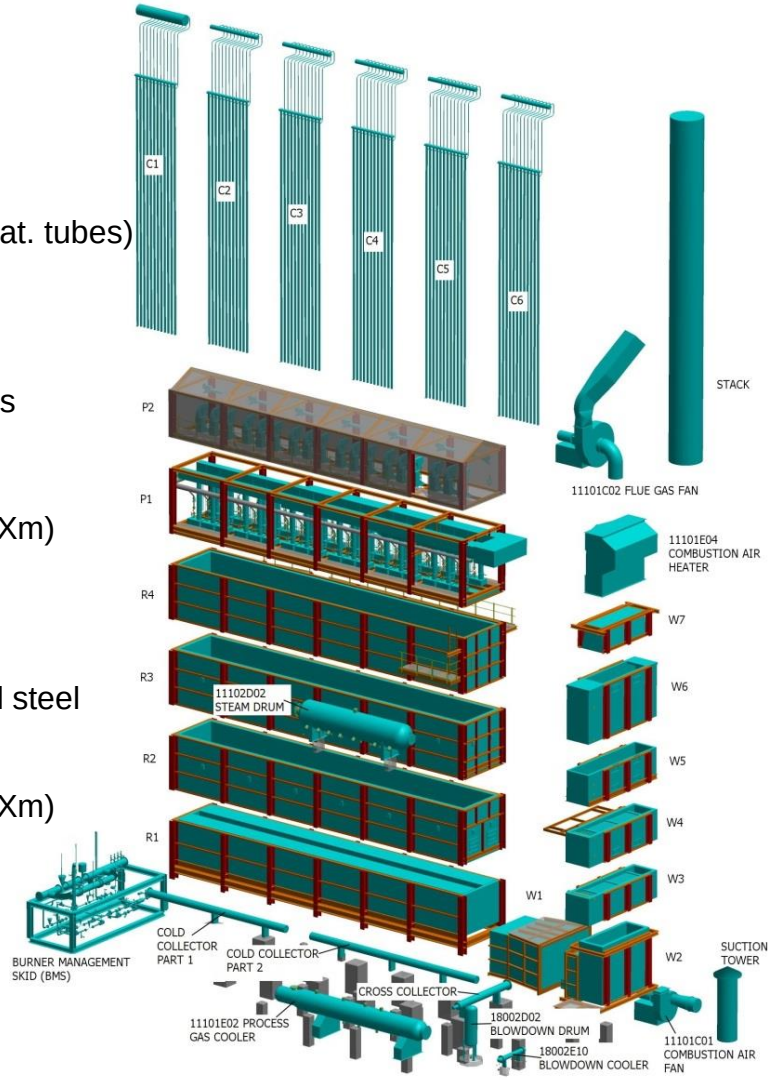
Reformer Box

Standardization:
- 1-row layout concept
- fixed diameter/length of reformer tubes
- fixed reformer tube pitch
- fixed burner configuration (2 burners / 4 cat. tubes)
- variable number of tubes (48/60/72)
- variable tube wall thickness

Modularization:
- 4 horizontal box and 2 penthouse modules
- harped reformer tubes installed at site
- cold header installed in two pieces
- All modules truckable (< 4.2m x 4.2m x XXm)

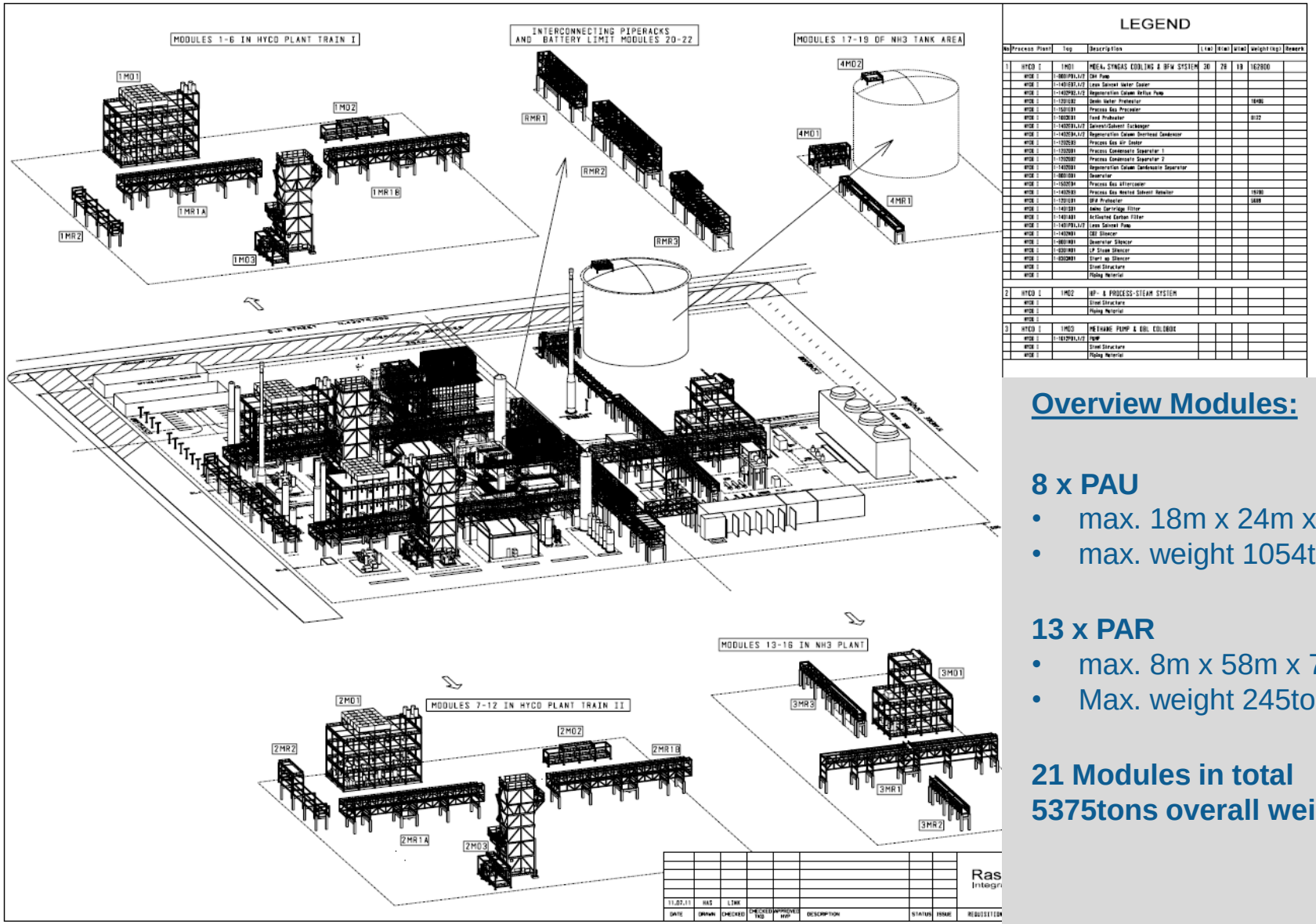
WHRU

- 10 self-supporting modules incl. structural steel
- Castable refractory preinstalled
- All modules truckable (< 4.2m x 4.2m x XXm)
- Maintenance platforms dressed at site
- Customized Convection Section
- Retractable bundles (optional)



Linde Engineering Modularization Experience

7.11 AlJubail10 - H_2 & Ammonia Plant



LEGEND

No	Process Plant	Tag	Description	L(m)	W(m)	H(m)	weight (kg)	Remark
1	HYCO I	1MO1	MEG4, SYNGAS COOLING & BFW SYSTEM	30	26	19	1629000	
	HYCO I	1-0801P01.1/2	CW Pump					
	HYCO I	1-1401E01.1/2	Lean Solvent Water Cooler					
	HYCO I	1-1402P02.1/2	Regeneration Column Reflux Pump					
	HYCO I	1-1201E02	Demin Water Preheater				18486	
	HYCO I	1-1501E01	Process Gas Precooler					
	HYCO I	1-1602E01	Feed Preheater				8132	
	HYCO I	1-1402E01.1/2	Solvent/Solvent Exchanger					
	HYCO I	1-1402E04.1/2	Regeneration Column Overhead Condenser					
	HYCO I	1-1202E03	Process Gas Air Cooler					
	HYCO I	1-1202D01	Process Condensate Separator 1					
	HYCO I	1-1202D02	Process Condensate Separator 2					
	HYCO I	1-1402D01	Regeneration Column Condensate Separator					
	HYCO I	1-0801E01	Deaerator					
	HYCO I	1-1502E04	Process Gas Aftercooler					
	HYCO I	1-1402E03	Process Gas Heated Solvent Reboiler				19700	
	HYCO I	1-1201E01	BFW Preheater				5600	
	HYCO I	1-1401D01	Amine Cartridge Filter					
	HYCO I	1-1401A01	Activated Carbon Filter					
	HYCO I	1-1401P01.1/2	Lean Solvent Pump					
	HYCO I	1-1402N01	CO2 Silencer					
	HYCO I	1-0801N01	Deaerator Silencer					
	HYCO I	1-0301N01	LP Steam Silencer					
	HYCO I	1-0202N01	Start up Silencer					
	HYCO I		Steel Structure					
	HYCO I		Piping Material					
2	HYCO I	1MO2	HP- & PROCESS-STEAM SYSTEM					
	HYCO I		Steel Structure					
	HYCO I		Piping Material					
	HYCO I							
3	HYCO I	1MO3	METHANE PUMP & BBL COLDBOX					
	HYCO I	1-1612P01.1/2	PUMP					
	HYCO I		Steel Structure					
	HYCO I		Piping Material					

Overview Modules:

8 x PAU
- max. 18m x 24m x 26m (WxLxH)
- max. weight 1054tons

13 x PAR
- max. 8m x 58m x 7.4m (WxLXH)
- Max. weight 245tons

21 Modules in total
5375tons overall weight modules

Agenda.

1. The Linde Ammonia Concept (LAC)™
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3. Modularization
4. Project Execution today

Modularization

Why?

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DE-RISKING

COST REDUCTION & SCHEDULE ATTAINMENT & HSE

DRIVERS

Environmental Conditions on Site	Labor Cost
▪ Controlled environment in yard or workshop ▪ Weather conditions ▪ Better quality, less rework ▪ Safety! controlled working environment ▪ Parallel construction work possible instead of sequential	▪ Access to skilled labor ▪ Low labor cost in yard or workshop ▪ No allowances to be paid

▪ Pre-commissioning work partially done in

Modularization

Effect on Project Execution!

TRADE-OFF´s

- Additional expenditures for investigation and or preparation of transport ways
- Module size restricted by general conditions of transport ways (max. height, max. weight…)
- Additional costs for Module Transport & Insurance (& poss. marine warranty surveyor MWS)
- Influence on static engineering to withstand transportation and erection stresses
- Additional steel structure
- DESIGN TO MODULE ; Engineering to be frozen earlier
- Installation sequence fixed
- Higher cost for bigger cranes or SPMTs on site
- Higher complexity due to limited space

Linde Engineering Modularization Experience

Linde Engineering Modularization Capabilities

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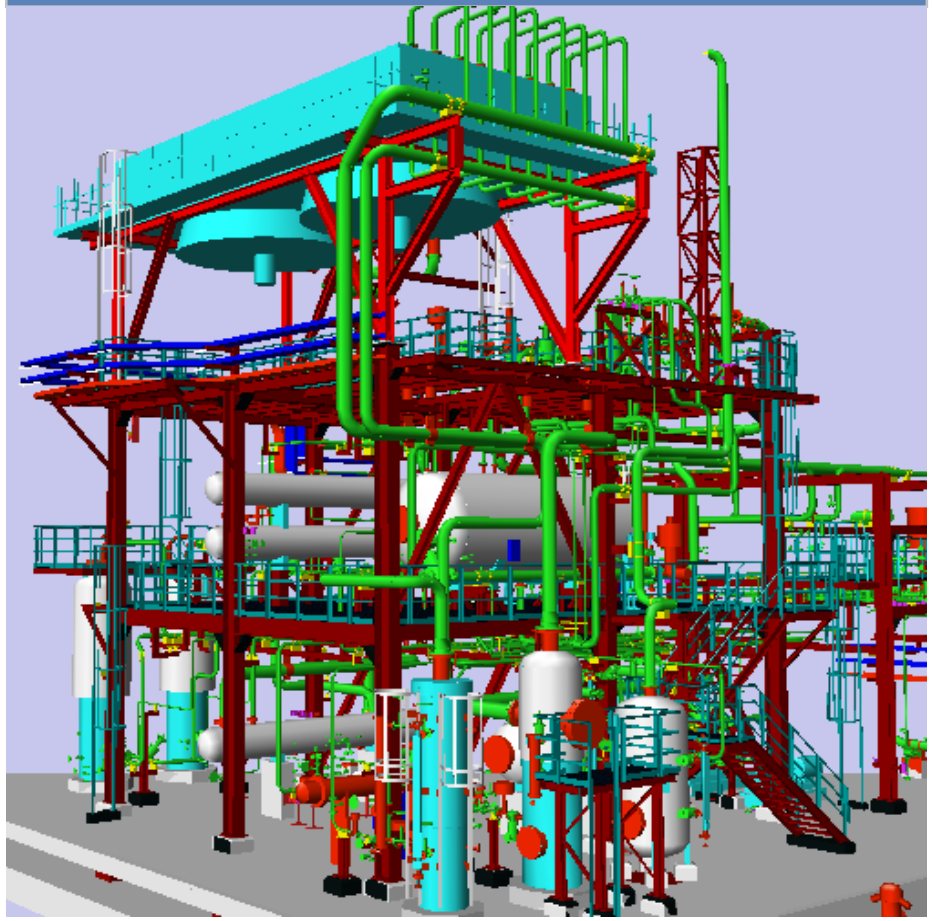
Stick built design



Module design

Modularization

Advantage of a “One Stop Shop”

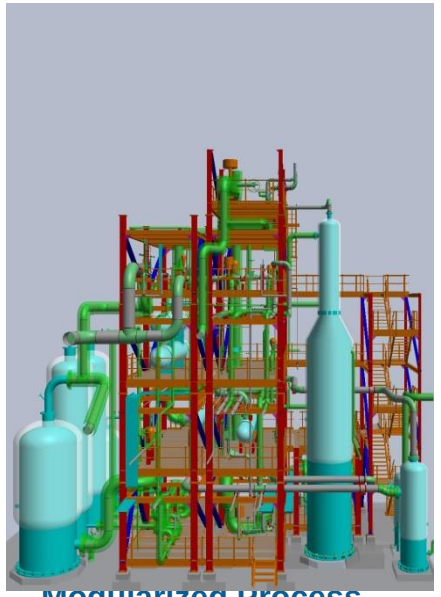
Design to Modularization

Linde (T-EPC) has Technology

- able to influence the front end engineering (Process Design, Eqiupment Design, System Engineering, etc.)
- optimized modularization layout design and arrangement.

Stick Built Process Unit

With horizontal Deaearator



Modularized Process Unit

Truckable modules

With vertical Deaearator

Linde Engineering Modularization Experience

Modules Types

Overview
Description of Module Types at Linde Engineering

Detailed information about module configurations, options, req. activities etc. is available and composed within document: 6AZ MOD L-PA-1002.001 (EN)

Modularization at Linde Engineering.
Modularization is used for transferring Stick Built Site works to remote location for fabrication and construction. Modularization implies the collection and assembling of single or pre-assembled units of several disciplines to one construction kit which is transported in one or few piece(s) and mounted at final installation location. Modules differ regarding several categories like plant size, design, transport & construction requirements, process functionality, configuration or others. Modularization is a specialized version of Pre-Fabrication.

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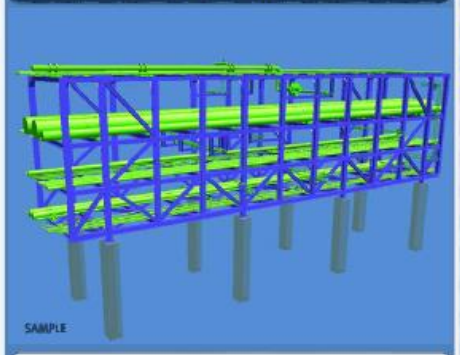
MODULES FOR PIPERACK

Linde Module

PAR
Pre-Assembled Rack – Transfer Rack



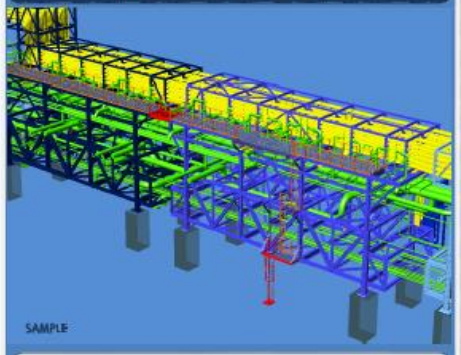
Main Characteristic:
- Transfer of operation or product fluids within pipes as main function e.g. production area to clients customizing area
- Commonly used between or outside of Battery Limit
- Tie-ins within this piperack are rare
- Items relevant for process are not a part of this type of module (exceptions are possible)
- EBI is prepared with trays only at fabrication areas by contractor, cabling is done one site

Short Description:
PAR will be used as piperack for transfer only. The structure consists of carrying steel frame with longitudinal framework, transfer pipes and applicable cable trays for electrical and instrumentation cabling but without any wire. Erection will be done preferred by lifting.
Module can contain temporary transport support structure if required.

Ideally all pipes are pressure tested by contractor and within fabrication area (at Yard). Cleanliness has to be ensured. Transport starts after drying, inertization and sealing of piping systems.

Linde Module

PAR+
Pre-Assembled Rack – Process Rack



Main Characteristic:
- PAR+ means LE classical usage of piperack within or as connection between Construction Areas and inside Battery Limit
- This type of module may contain items relevant for process e.g. Control Valves but excluding tagged equipment e.g. Heat Exchanger
- Access and maintenance areas are integrated
- EBI is prepared with trays and predefined items are fully connected to junction boxes (inside module)

Short Description:
PAR+ will be used as piperack with process relevant systems with all required integrated pipe components. Therefore layout, design and size will differ significantly from PAR. Access and maintenance areas are integral part of such called process piperacks. Tagged equipment will not be implemented into PAR in general. For EBI all cable trays are installed and elected systems can be wired and connected to junction boxes. Module can contain temporary transport support structure if required.

Ideally all pipes are pressure tested by contractor and within fabrication area (at Yard). Cleanliness has to be ensured. Pre-commissioning is performed at contractor area. Preparatory actions for commissioning shall be done by contractor. Transport starts after drying, inertization and sealing of piping systems.

MODULES FOR PROCESS UNITS & SECTIONS

Linde Module

PAU
Pre-Assembled Unit – Small / Separated

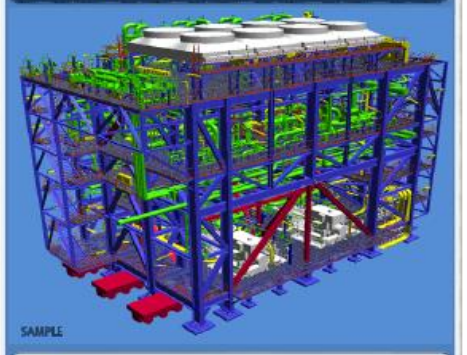
Main Characteristic:
- Small modules contain items relevant for process e.g. Control Valves incl. tagged equipment e.g. Heat Exchanger
- Transport Limitation by road traffic regulations defines size of module
- Sandwich modules – several PAUs will be connected to one structure (module)
- StarLNG or HyComp Modules are PAUs
- EBI is prepared with trays and elected items are fully connected to junction boxes (inside module)
- Special solution of module type PAU are all containerized solutions which are flexible in content but restricted to standard container sizes and types

Short Description
In general PAU is used for all structures with process elements. Most of tagged equipment categories may be part of PAU. The size of PAU is limited by appropriate traffic regulations.
Special applications for PAU are existing concepts from StarLNG or HyComp with separated modules combined on site. For EBI all cable trays are installed and elected systems can be wired and connected to junction boxes. Module may contain temporary transport support structure if required and especially integrated main base frame for transport.

Ideally all pipes are pressure tested by contractor and within fabrication area (at Yard). Cleanliness has to be ensured. Pre-commissioning is performed at contractor area. Preparatory actions for commissioning shall be done by contractor. Transport starts after drying, inertization and sealing of piping systems.

Linde Module

PAU+
Pre-Assembled Unit – Large / Single Module



Main Characteristic:
- In principle identically with PAU with one additional unique feature to exceed normal road transport size and weight
- Module contains complete process sections with all items required
- Transport limitation by economic feasibility – heavy load transport is very probably
- PU, VAU or SKID can be integrated at fabrication yard or site
- EBI is prepared with trays and predefined items are fully connected to junction boxes (internal module)
- Speciality: Linde PU-Box and PSA & TSA is conform to PAU+ definition but will called PU-Box or (?)SA-Skid based on historical issues and state of the art at LE

Short Description:
PAU+ connotes a single module with the possibility for integration of other module types like VAU or SKID and the option to join with other PAU+. Configuration and possible contained elements are similar to PAU.
For EBI all cable trays are installed and elected systems can be wired and connected to junction boxes. Module may contain temporary transport support structure if required and especially integrated main base frame for transport.

Ideally all pipes are pressure tested by contractor and within fabrication area (at Yard). Cleanliness has to be ensured. Pre-commissioning is performed at contractor area. Preparatory actions for commissioning shall be done by contractor. Transport starts after drying, inertization and sealing of piping systems acc. requirements.

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Linde Engineering Modularization Experience

Gofer (GER) – Exchange of Furnaces

Pre-Commissioning achievements:

- Assembly completely apart rom the actual plant site
- Hot testing and drying of the brickwork at the assembly site before the transport
- Provisional supply lines and mobile compressors allow pre-commissioning

Linde Engineering Modularization Experience

Hammerfest (NOR) – Antwerp (B) Cold Box

The challenge:

- Tricky conditions on plant site in Hammerfest (weather, space, labor costs)
- Overall weight of cold box: 3500to
- Height: 65m

The solution:

- Assembly of Cold Box in Antwerp close to harbor
- Utilization of SPMTs under whole footprint of cold box for transport to barge
- Shipping of assembled Cold Box to Hammerfest

Advantages of modularization:

- Assembly of Coldbox off site (lower labor costs)
- Use of assembly area with fewer restrictions concerning space

Linde Engineering Modularization Experience

Hammerfest (NOR) – Cadiz (ESP) Process Barge

The challenge:

- Tricky conditions on plant site in Hammerfest (weather, daylight, space, labor costs)
- Availability of skilled personnel in Hammerfest

The solution:

- Assembly of process plant/barge unit in Cadiz (ES)
- Shipping of the barge/plant unit to Hammerfest
- Utilization of a floating barge as foundation for the process plant
- Parking of the barge in a flooded slot
- Drying of slot and fixing the barge as foundation
- Use of multiple yards location

Advantages of modularization:

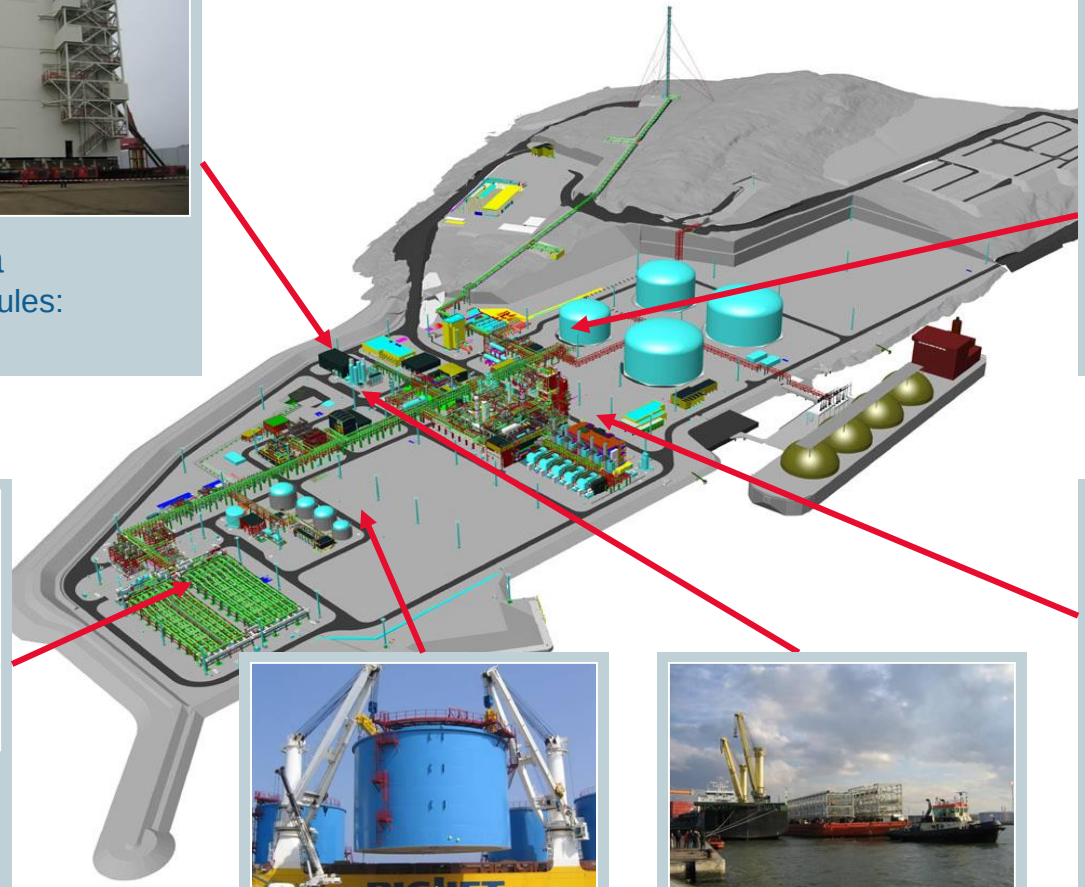
- Assembly of plant off site (lower labor costs)
- Use of assembly area with few restrictions concerning space
- Reducing of heavy equipment for module installation at site

Linde Engineering Modularization Experience

Hammerfest (NOR) – Cadiz (ESP) Process Barge

Heerema
MEG-Modules:
4 800 tons

Fabricom
Cold Box: 3 500 tons



Heerema
SC-Modules:
9 300 tons

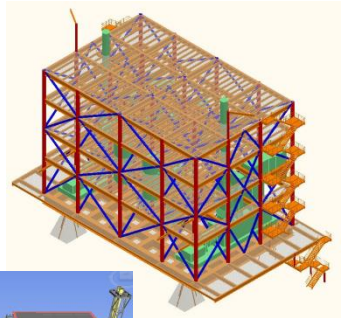
Tanko Italia
MEG-Tanks:
1 300 tons

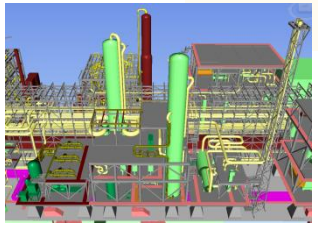
Fabricom
PAUs+PARs:
10 600 tons

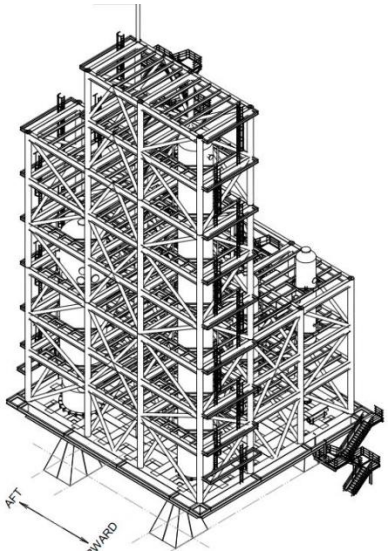
Dragados
Process plant 35 000 tons

Linde Engineering Modularization Experience

Cash Maple (AUS) - FLNG







The challenge:

- Integration of LNG plant on ship hull
- Minimization of fixed capital
- Restricted spatial conditions on ship

The solution:

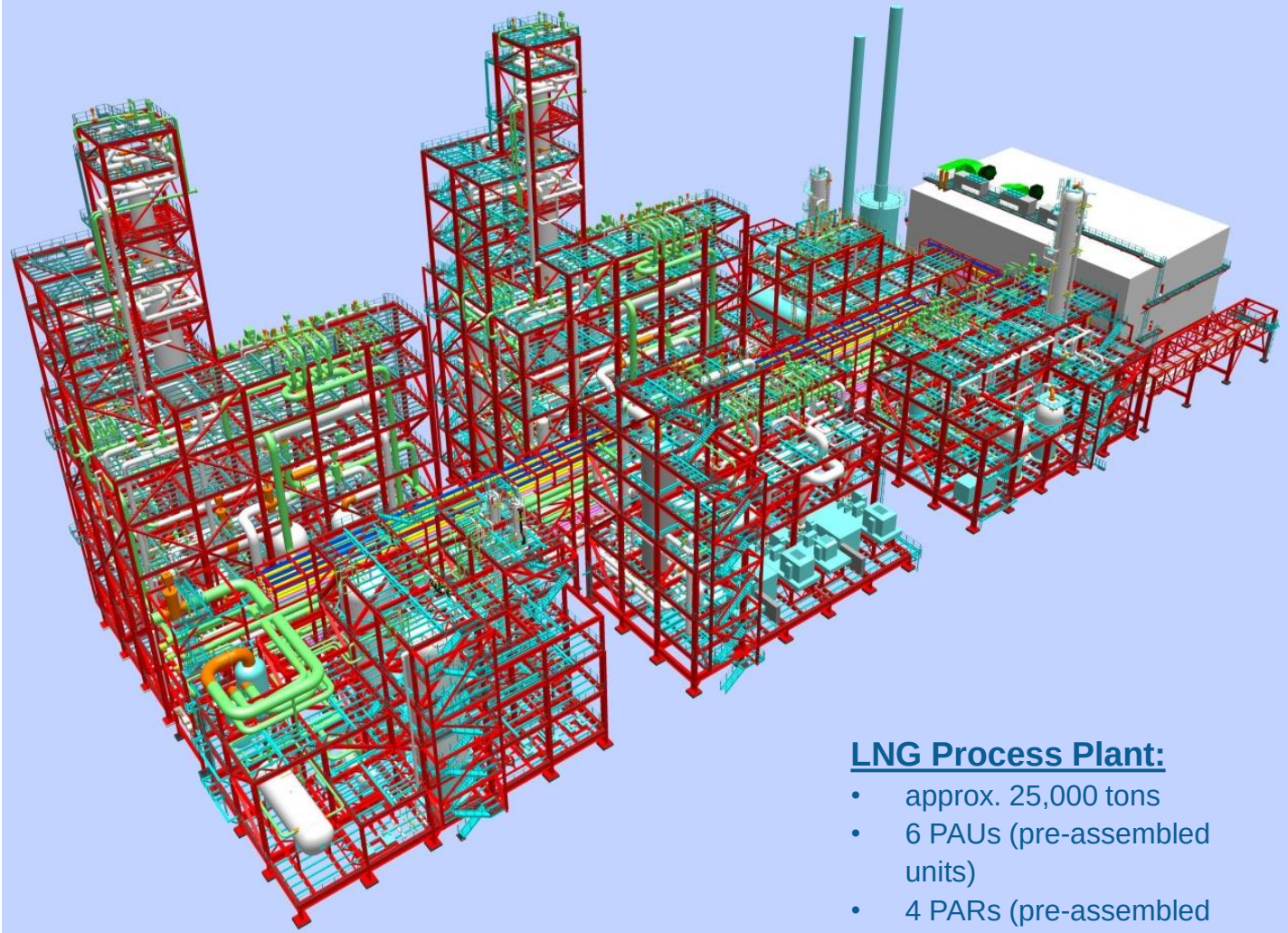
- High degree of modularization instead of stick-built elements
- Parallel assembly of ship hull and process modules

Advantages of modularization:

- Minimization of the required space on deck
- Reduced duration of assembly ➔ minimum of fixed capital
- Assembly in area with fewer spatial restrictions and well-rehearsed assembly processes

Linde Engineering Modularization Experience

British Columbia (CAN) – LNG Plant



LNG Process Plant:

- approx. 25,000 tons
- 6 PAUs (pre-assembled units)
- 4 PARs (pre-assembled racks)
- 1 Module E & I

The challenge:

- Remote location of site with poor connection to any infrastructure
- Climate and weather conditions at site
- Existing plant has to be dismantled

The solution:

- Shift of maximum workload from site to Module Yard

Advantages of modularization:

- Big modules reduces connection works
- Max. reduction of construction activities at site

Linde Engineering Modularization Experience

Karratha (AUS) – Rayong (THA) NRU and Cold Box

Load out Process Module Thailand

Key Figures:
(Dimension & Weight)

Proc. Module:
35,0 x 20,5 x 27,0 (m) (L/W/H)
Weight: 1400 tons

Erected Process Module Karratha (AUS)

"Sail away" Process Module

Agenda.

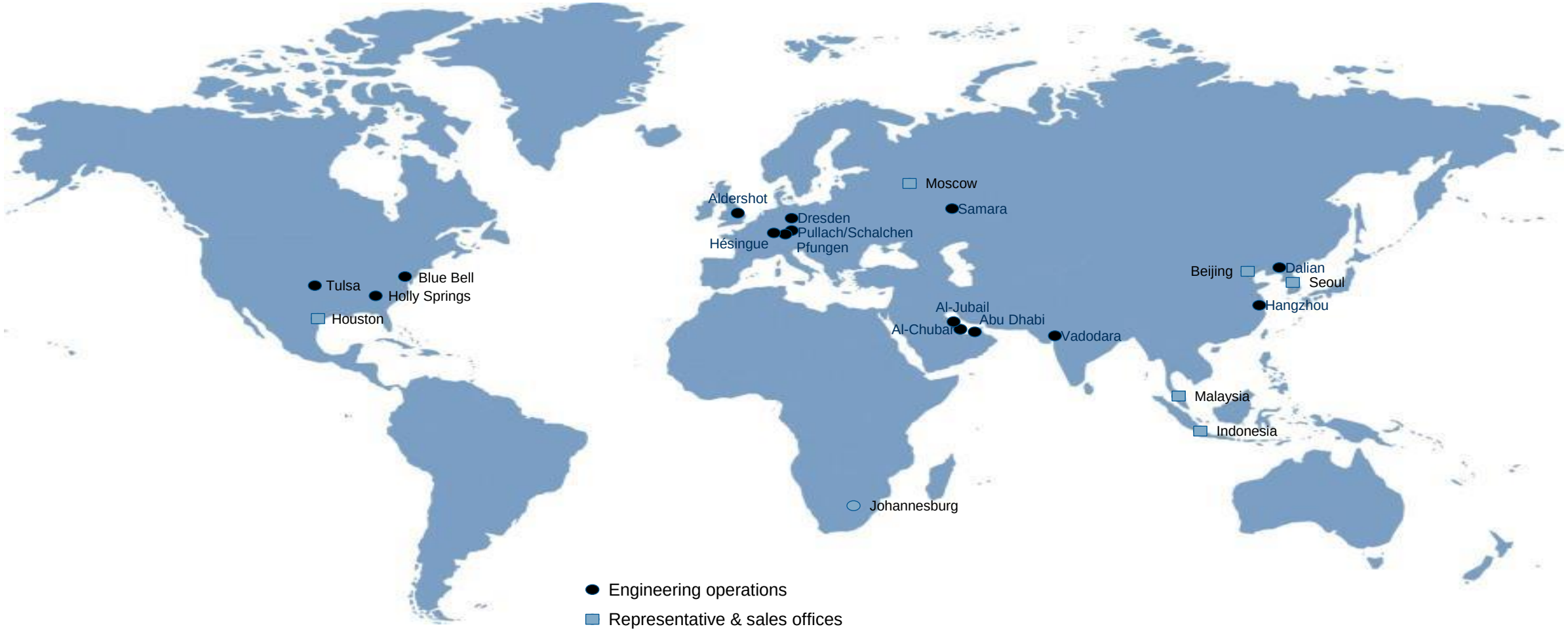
1. The Linde Ammonia Concept (LAC)™
2. Standardized and Modularized Plants
3. Modularization
4. Project Execution today

Linde Engineering Project Execution
A central function

Efficient organisation	**Clearly structured processes**	**Competence in execution**	**4000+ convincing arguments**

Linde Engineering Project Execution

Global Operation Hubs



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Linde Engineering Project Execution

Our competitive advantage in project execution

Topics	Content
1) Efficient organisation	▪ We know the clients' perspective because Linde Gas is a major operator ▪ Global project execution setup ▪ Globally spread procurement centers guarantee top notch quality ▪ Different engineering hubs ensure highest level of competitiveness ▪ EPC services with focus on own technology ▪ Numerous partnering options
2) Clearly structured processes	
3) Competence in execution	
4) 4,000+ convincing arguments	

Linde Engineering Project Execution

Our competitive advantage in project execution

Topics	Content
1) Efficient organisation	
2) Clearly structured processes	▪ Integrated Management System ▪ Pre-defined work split models ▪ Clearly defined Division of Responsibility ▪ Structured change management ▪ Focus on quality and safety
3) Competence in execution	
4) 4,000+ convincing arguments	

Linde Engineering Project Execution

Our competitive advantage in project execution

Topics	Content
1) Efficient organisation	
2) Clearly structured processes	
3) Competence in execution	▪ Top project managers developed within our own organization ▪ Proprietary equipment/ own manufacturing of key components ▪ State-of-the-art tools ▪ Standardised gate reviews ▪ Continuous risk management
4) 4,000+ convincing arguments	

Linde Engineering Project Execution

Our competitive advantage in project execution

Topics	Content
1) Efficient organisation	
2) Clearly structured processes	
3) Competence in execution	
4) 4,000+ convincing arguments	▪ Over 4,000 reference plants ▪ Flawless transition from sales to execution ▪ Standardised and customised plants ▪ Tailored export financing

Linde Project Execution

Structured Processes: Project gate reviews

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Linde

Sales Phase → **Execution Phase**

R0	R1	R2	R3	R4	R5	R6	R7	R8
Bid/no-bid decision	Proposal challenge & approval	Contract award/Execution start	Basic completed	Ext. basic/ 30% model completed	60% model completed	90% model completed	Ready for commissioning	Plant hand-over/ project close out
❖ Bid/no Bid Decision	❖ within proposal approval meeting	❖ within 4 weeks after execution start	❖ after PID D2/E2 release *1	❖ after 30% review	❖ after 60% review	❖ after 90% review	❖ after mechanical completion	❖ after plant performance confirmed
Phase Gates (0) Evaluation	Phase Gates (1) Strategy (2) Definition (3) Estimating (4) Challenge [A] Concept 1 [B] Concept 2	Phase Gates (5) Negotiation (6) Mobilization (7) Organization [C] Concept 3	Phase Gates (8) Execution [D] Basic 1 [E] Basic 2	Phase Gates (8) Execution [F] Extended basic	Phase Gates (8) Execution [G] Detail 1	Phase Gates (8) Execution [H] Detail 2/ Construction 1	Phase Gates (8) Execution [J] Detail 3/ Construction 2 [K] Construction 3 [L] Mechanical completion	Phase Gates (9) Closure [M] Commissioning [N]) Start-up [P] Initial operation [Q] As-built

Rx Project review (milestone) (X) Project management gate [X] Engineering gate

1) To be decided by Project Manager

Efficient organisation	Clearly structured processes	Competence in execution	4000+ convincing arguments

Collaborate. Innovate. Deliver.

Thanks for your attention.

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