



# Hydrogen



Air Liquide Hydrogen Unit,  
Trinidad

## Technology Leader

As the global leader in engineering and contracting for synthesis gas technologies, Lurgi can build on vast experience in engineering, procurement and construction of hydrogen plants. Focusing on customized solutions that reflect individual client and project requirements Lurgi provides the full range of services from technology packages to ownership of large scale industrial lump sum turn key projects.

In addition to Lurgi's outstanding experience of designing over 110 steam methane reforming (SMR) units worldwide, the integration of S/U experience, the results of significant R&D efforts and the long term operational experience led from conventional SMR to the proprietary design of today's Lurgi Reformer® technology.

As a member of the Air Liquide Group, Lurgi has access to an extended network of R&D and engineering execution centers that possess thorough understanding of clients' needs and market conditions in all regions of the world.

## Safety and Environment

Lurgi's hydrogen plants are designed to meet the most stringent international safety and environmental standards throughout the design, construction and operation of the plant.

## Customized Solutions

The majority of the hydrogen produced worldwide is consumed in refineries and petrochemical industries. Hydrogen is also used as transportation fuel and for a large number of industrial processes such as the production of metals, electronics, edible fats and oils, or production of float glass.

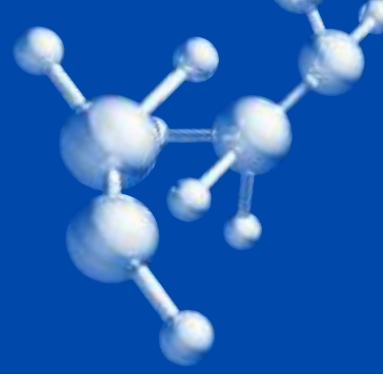
This variety of established and future oriented hydrogen offtakers leads to solid growth rates in global hydrogen demand, of which today more than 95 % is covered by units applying SMR of hydrocarbon feedstocks.

Refinery and chemical companies have various options to cover hydrogen demands including:

- Recovering hydrogen from refinery fuel gas or chemical unit off-gases
- Revamping existing steam reforming units



Petronas Malaysia  
Syngas Complex  
Kuantan, Malaysia



- Building and operating a new steam reforming units
- Opting for an alternative hydrogen production method such as gasification technologies
- Importing hydrogen over the fence from an industrial gas supplier

For all options, Lurgi commands the full range of engineering services to develop the optimum technology solution for the individual client concept.

Strictly following the motto Lurgi – your clean conversion partner, the project specific customization process for Lurgi Reformer® typically includes:

- Closest cooperation with client representatives
- Optimization of export steam flows with regards to cost and efficiency
- Optimization of the integration of new units into existing site concepts
- Optimization of the generic plant concept, e.g. with regard to co-generation of complementary products such as CO, NH<sub>3</sub> or MeOH
- Optimization of project implementation schedule
- Optimization of plant pre-fabrication and modularization concepts

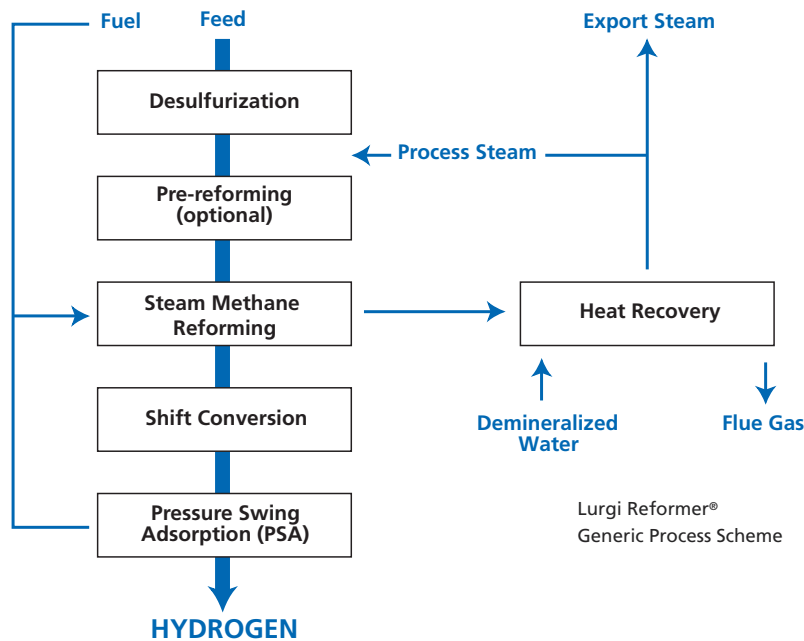
- Optimization of plant design with regard to multiple feedstock utilization
- Optimization of plant availability and reliability with regard to capital expenditure

In a nutshell the Lurgi Reformer® technology provides:

- Proven technology
- Highly customized design solutions
- Easy and smooth operation
- Superior firing and load control
- Best in class emission levels

The Lurgi Reformer® is especially outstanding due to:

- Top fired reformer box
- High energy efficiency
- Operational availability higher than 99 %
- High operational reliability ensured by 2 out of 3 voting systems
- Optimized turn-around cycles
- Low utility consumption
- Low maintenance costs
- Low overall capital expenditure



## Process Scheme

The generic process scheme comprises feed desulfurization, SMR, shift conversion and hydrogen purification.

The hydrocarbon feedstock is mixed with recycled hydrogen. Desulfurization comprises two process steps, organic sulfur compounds are converted to  $H_2S$  in the presence of a hydrogenation catalyst and  $H_2S$  is adsorbed.

The desulfurized feed is mixed with process steam at an optimized steam to carbon ratio and superheated prior to entering the primary reformer. In the presence of a catalyst the mixed feed is converted to a reformed synthesis gas containing  $H_2$ ,  $CO_2$ ,  $CH_4$ ,  $N_2$  and steam inside the tubes of the primary reformer.

The  $CO$  in the reformed synthesis gas is water gas shifted for increased hydrogen yields by means of sweet water gas shift process units such as high temperature shift or high temperature shift plus low temperature shift process units.

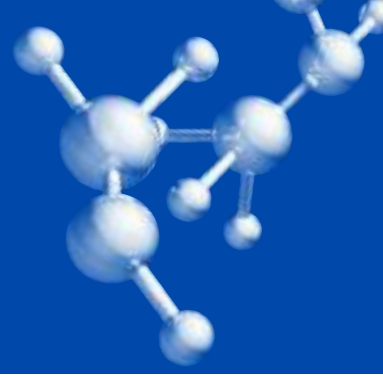
In the hydrogen purification unit, hydrogen is separated from the shift gas stream by pressure swing absorption or membrane units to provide continuous and constant hydrogen product flow rates.

The reformer box is heated by firing the off-gas from the hydrogen purification unit and by make-up process fuel with forced draught burners in the top section. The combustion air required is routed by a combustion air fan to the burners after pre-heating. The hot flue gases exit the reformer box through a refractory-lined duct and are routed to the flue gas stack after excess heat being recovered in the heat recovery section.

Steam generated by waste heat of reformed gas from the SMR is utilized as process steam while the excess is exported.



Lurgi Combined Reforming Plant,  
KMI, Indonesia



## Process Options

To achieve an optimum customization of the Lurgi Reformer® plant design, Lurgi offers a full range of process options.

### Pre-Reforming

For the conversion of higher-molecular hydrocarbons and optimization of overall energy efficiency, Lurgi offers tailor-made pre-reforming process units as an integral part of the hydrogen plant.

### Autothermal Reforming

Pure autothermal reforming can be applied for syngas generation whenever light natural gas and oxygen are available as feedstocks. The desulfurized and optionally pre-reformed feedstock is reformed with steam to synthesis gas at high pressures using oxygen as reforming agent. The process yields carbon-free synthesis gas and offers great flexibility over a wide operating range. The synthesis gas is compressed by a single casing compressor with integrated recycle stage to the required battery limit pressure.

As the industry leader in autothermal reforming, Lurgi presents a large number of plant references starting as early as the 1950s.

### Lurgi Combined Reforming

For heavy natural gases and oil-associated gases, the most economic way to produce synthesis gases is a combination of autothermal reforming and steam reforming. After desulfurization, a branch of the feed gas is processed in a steam reformer at high pressure and relatively low temperature. The reformed gas is then mixed with the bypassed feed gas and reformed to synthesis gas at high pressure in the autothermal reformer. This concept has become known as the Lurgi Combined Reforming process.

The main advantages of the Lurgi Combined Reforming process is the feed gas bypass of the steam reformer and the low process steam consumption translating into reduced energy consumption as well as lower capital expenditure.



HP POX Test Facility  
Freiberg, Germany

### Partial Oxidation

Lurgi's proprietary Multi Purpose Gasification MPG® technology is suited for the non-catalytic partial oxidation of solids, gaseous or liquid feedstocks for the production of large quantities of synthesis gas. With over 45 years of active experience in gasification technologies and over 75 units on-stream, Lurgi is the right partner to maximize advantages of the MPG® technology due to:

- Maximum feedstock flexibility
- Extended guaranteed burner lifetimes
- Inherent plant safety by pressurized cooling water system
- Long reactor lifetimes due to moderate, uniform wall temperature profiles
- Sophisticated designs for boiler and quench configuration

In combination with raw gas shift and raw gas purification technologies, MPG® is the superior choice for large scale hydrogen plants based on heavy residue feedstocks such as oil sands, vacuum residues, visbreaker residues or asphalt.

### Water Gas Shift

Depending on the process optimization with regard to steam requirement, feedstock type and quality, and fuel valuation, Lurgi proposes the optimum solution for water gas shift systems:

For hydrogen plants designed for boiler mode operation by sweet water gas shift process units with upstream feedstock desulfurization:

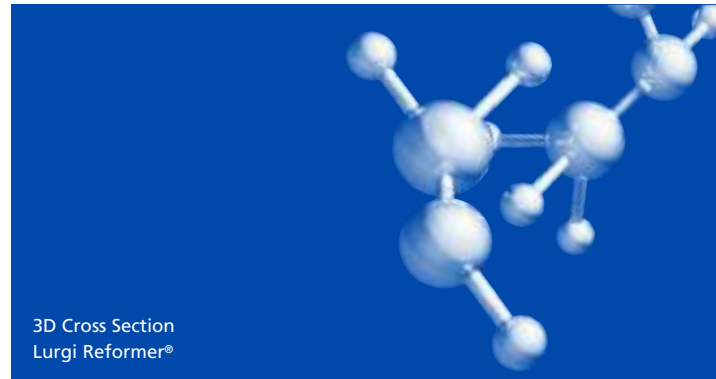
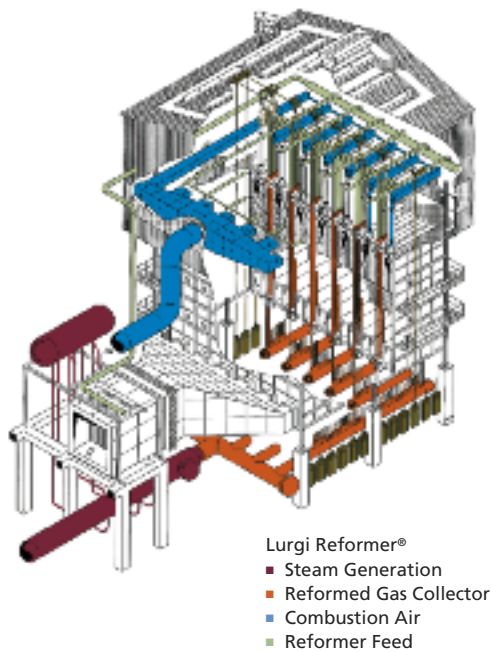
- High temperature shift followed by a hydrogen purification
- High temperature shift followed by a low temperature shift and methanation process steps
- Medium temperature shift followed by a hydrogen purification

For hydrogen plants designed for quench mode operation by a raw gas shift process unit followed by a synthesis gas purification process step such as Rectisol®.

### Hydrogen Purification

Depending on process conditions, required hydrogen quality and plant capacity, Lurgi offers three options for the hydrogen purification process step:

- Pressure swing adsorption (PSA) as the standard solution
- Low temperature shift plus downstream methanation process units for hydrogen plants with high hydrogen yields
- Membrane units for low capacity hydrogen units or hydrogen units with specific quality requirements



### CO<sub>2</sub> Capture

Lurgi's proven and worldwide recognized technology portfolio of CO<sub>2</sub> capture technologies include physical or chemical washes such as:

- Rectisol®
- MDEA
- Amine washes

### Emission Control

Reflecting increased requirements of environmental regulations and clients or project policies, Lurgi offers a toolbox of technologies to lower the environmental impact of hydrogen plant operations which includes:

- State of the art noise abatement
- In-house portfolio of worldwide recognized CO<sub>2</sub> capture technologies
- Inherent plant safety by pressurized cooling water system
- Expertise in NO<sub>x</sub> reducing burner technologies
- Latest generation of selective catalytic reduction technologies (SCR) to minimize nitrous oxide flue gas emissions

## Success through Technology

### Lurgi Reformer®

The heart of the hydrogen plant is the Lurgi Reformer®. Lurgi's advanced design combines outstanding operational characteristics with excellent maintenance features leading to superior operability and low investment and operating costs.

Distinct features of the Lurgi Reformer® proprietary design are:

- Large single train capacities of up to 1,000 tubes per train available
- Top fired reformer box for minimum number of burners
- Horizontal convection section for reduced maintenance efforts
- Cold header design for minimized thermal stress and refractory protection
- Flexitube design for higher design and operating temperatures
- Counter-weight tube support design for minimized mechanical stress
- Horizontal or vertical waste heat recovery system designs available
- High modularization levels for increased quality of mechanical equipment, piping and instrumentation



KHARG - Burner Row

### Availability and Reliability

Lurgi is setting best in class standards with regards to plant availability and reliability by:

- Integrating design experience from over 110 Lurgi Reformer® units and over 1 million hours of operation in more than 30 Air Liquide hydrogen plants.
- Conducting extensive availability studies during the design phase of each project
- Typical designs resulting in on-stream factors larger than 99 % for normal operation
- Proven designs for turn-around cycles of up to 5 years

### Hydrogen Quality

The hydrogen produced is of high purity 99.9–99.999 vol. %, with low impurity levels, such as a CO content below 10 vol. ppm.

### Utility Consumption

For a Lurgi Reformer® based medium sized hydrogen plant utilizing light natural gas as feedstock, typical consumption figures per 1,000 Nm<sup>3</sup> hydrogen product amount to

Feed and Fuel	400 – 420 Nm <sup>3</sup>
Make-up BFW	1.0– 1.5 t

Cooling Water	2.5 – 3.0 m <sup>3</sup>
Electricity	approx. 17 kWh
Export Steam	0.60–0.90 t

Typical consumption figures vary depending on hydrogen quality, customization and optimization of the plant design and export steam valuation.

### Load Control

- Fully automatic blend and change of various feedstocks
- Fully automatic load changes up to 3 % capacity per minute
- Operation at minimum steam to carbon ratios

### Firing Control

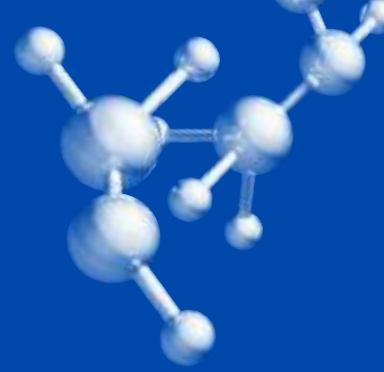
- Peaks of PSA tail gas flow and composition are compensated by fuel gas
- Stable reformed gas temperature ensured
- Minimum oxygen content in the flue gas ensured

### Cost Efficiency

Lurgi Reformer® technology is the result of optimization and customization processes with regard to capital and operational cost.



Sipchem CO Plant  
Kingdom of Saudi Arabia



The Lurgi Refomer® offers reduced capital expenditure due to:

- Top fired designs
- Multiple tube rows limiting the number of burners
- Large single train plant capacity
- High level pre-fabrication and modularization

Lurgi Refomer® design results in reduced operating cost due to:

- High operating pressures at the Lurgi Refomer® outlet
- High feed preheating temperatures
- Completely maintenance free catalyst tube inspection system

#### Advanced Hydrogen Management

Advanced hydrogen management systems are the key to hydrogen plant efficiency and availability. The Lurgi Refomer® features the most sophisticated control systems resulting in exceptionally high on-stream factors.

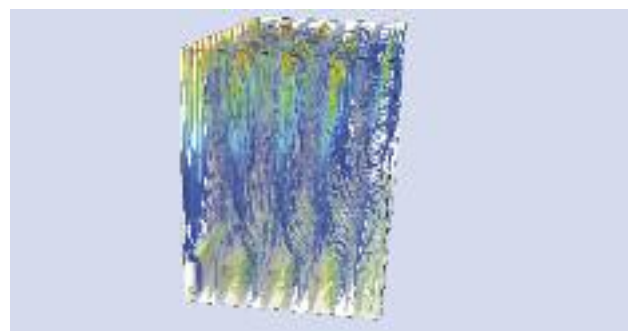
#### PRO-EN™ Services

Profitability enhancement services are the backbone of hydrogen optimization and management solutions. Customized, proprietary state of the art simulation software

offers industry-leading hydrogen optimization studies that are customized to meet client and project needs and budgets.

#### Design Tools

Lurgi applies state-of-the-art plant engineering and software tools such as 3D modeling. Computational Fluid Dynamics (CFD) models are used to generate optimized design solutions at different scales: from the distribution piping to the full furnace using a dedicated in-house 3D tool. In addition, Lurgi's multi-scale computational approach helps creating new mathematical models for complex fluid designs.



CFD Model Sipchem



3D Model  
Air Liquide  
Rozenburg, Netherland

## Operational Excellence

### References

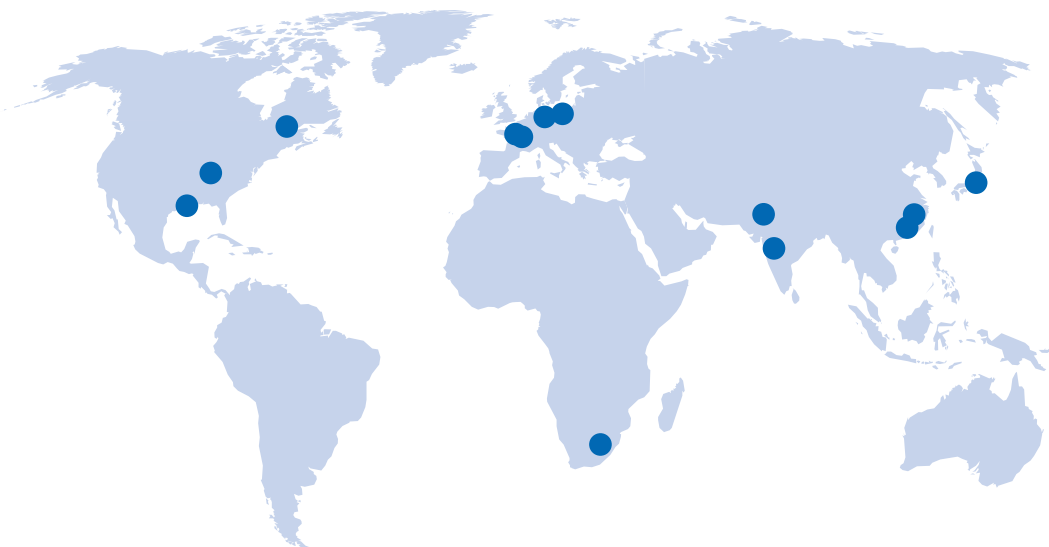
The benefit of long years of engineering experience for steam reforming plants is available and applied in order to achieve optimum results.

- Plant capacities up to 250,000 Nm<sup>3</sup> / h hydrogen production
- Worldwide more than 30 hydrogen reference plants
- Worldwide more than 110 Lurgi Reformer® reference plants
- Over 120 years of engineering experience

### Intelligent Solutions

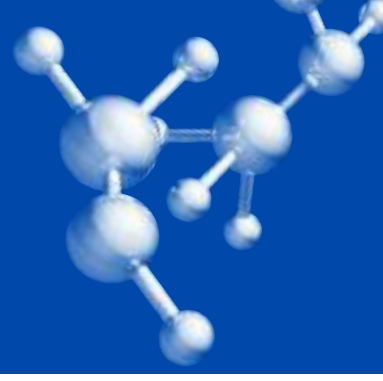
Nearly 1,500 employees are working for Lurgi world-wide. More than 15 % are engaged in finding technological solutions in the company's technology and R&D units. After all, each client and each project have their own specific design and operational conditions calling for intelligent and integrated concepts. The aspects of feedstock availability and quality are discussed in multidisciplinary teams of experts to optimize solutions with best-in-class engineering practices.

Process optimizations require concrete numerical data, computer assisted simulation results and considerable experience. This expertise is indispensable when decisions have to be made. Lurgi contributes to every project the know-how accumulated in more than 50 years of engineering experience for synthesis gas plants.





Hydrogen Plant, Grupa LOTOS  
Refinery in Gdańsk, Poland



### Competence in Project Execution

Lurgi's execution centers around the world allow for a fast and efficient support of clients and projects in their respective location. Modern communication structures, fast know-how transfer and the complete service portfolio are the key to success for Lurgi's clients and projects.

### Scope of Services

Lurgi provides technology solutions executed in full-service operating centers worldwide. Lurgi's activities cover all phases of synthesis gas projects from financing through design, procurement, start-up services and operation including:

- Consulting services
- Market studies
- Conceptual studies
- Feasibility studies

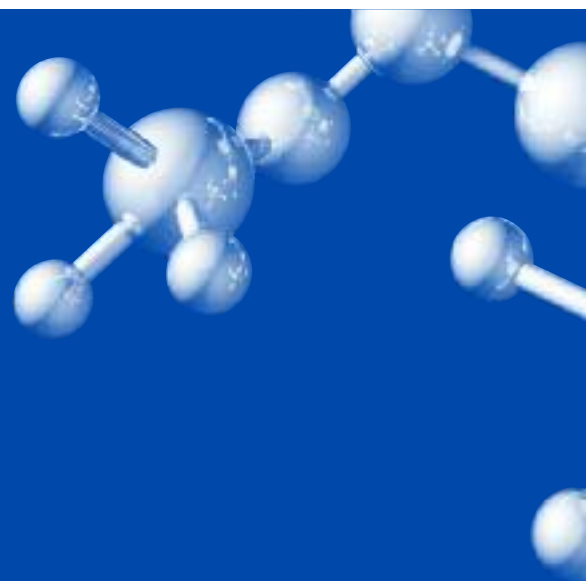
- Product marketing
- Financing
- Investment analysis
- Contracting
- Value engineering
- Authority engineering
- Basic and detail engineering
- Global sourcing
- Construction
- Construction supervision
- Start-up services
- Operation and maintenance
- Technical services

In addition, project management consulting services are offered to provide comprehensive project management and associated services for large scale synthesis gas projects.

Lurgi is a leading technology company operating worldwide in the fields of process engineering and plant contracting. Based on syngas, hydrogen production and clean conversion technologies for fuels or chemicals Lurgi offers innovative solutions that allow the operation of environmentally compatible plants with clean and energy-efficient production processes.

Its technological leadership is based on proprietary and exclusively licensed technologies which aim to convert all carbon energy resources (oil, coal, natural gas, biomass, etc.) in clean products.

Lurgi is a member of the Air Liquide Group.



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