Methanol and Derivatives
Proven technologies for optimal production
Air Liquide Group

World leader in gases, technologies and services for Industry and Health

Air Liquide is present in 80 countries with approximately 68,000 employees serving more than 3 million customers and patients.* Oxygen, nitrogen and hydrogen have been at the core of the company’s activities since its creation in 1902. Air Liquide’s ambition is to be the leader in its industry, delivering long-term performance and acting responsibly.

Air Liquide Global E&C Solutions

A technology partner of choice

Air Liquide Global E&C Solutions, the engineering and construction activity of the Air Liquide Group, builds the Group’s production units (mainly air gas separation and hydrogen production units) and also supplies external customers with its portfolio of technologies. Its industrial gas, energy conversion and gas purification solutions enable customers to optimize the use of natural resources.

Air Liquide Global E&C Solutions covers the entire project life-cycle: license engineering services / proprietary equipment, high-end engineering & design capabilities, as well as project management & execution services. Its exclusive and innovative technologies are making a contribution to the transition of the energy sector.

With more than 1,600 patents and 3,500 employees, Air Liquide Global E&C Solutions is at work connecting people and ideas everywhere to create advanced technologies to solve customer issues and position Air Liquide for growth over the long term.

Our full suite of technologies

- Liquefied Natural Gas
- Cryogenics
- Hydrogen
- Syngas
- Petrochemicals
- Natural Gas Treatment
- Sulfur
- Standard Plants
- Oleochemicals

*Following the acquisition of Airgas on 23 May 2016
Expert design and execution

The most comprehensive range of methanol technologies

Air Liquide Global E&C Solutions’ Lurgi methanol technologies are the most comprehensive range of solutions for syngas generation, methanol synthesis, methanol distillation and methanol conversion to propylene or gasoline. With over 50 years experience in plant design, engineering, procurement and construction, our production facilities are among the safest and most reliable on the planet and produce the highest quality product.

We can provide a complete solution, from the feasibility study and up to and including the construction and delivery of a fully operational turnkey facility. Our project teams are qualified to provide permitting studies, licensing packages, integrated engineering and procurement, and construction management. We can also integrate a broad range of equipment into your existing plant.

Our methanol-based plants can generate from 250 to 10,000 metric tons of methanol per day from any feedstock. They are reliable, safe and comply with the strictest environmental standards.

As the world’s No. 1 supplier of high-capacity methanol plants, we have developed many new and innovative technologies, such as:

- Low Pressure (LP) methanol production (2,500 tpd)
- Lurgi MegaMethanol™ (5,000 tpd)
- Lurgi GigaMethanol (10,000 tpd)
- Lurgi MTP™ methanol-to-propylene (1,410 tpd)
- Lurgi GTP™ gas-to-propylene (1,410 tpd), by combining Lurgi MegaMethanol™ and Lurgi MTP™ technology
- G2G™ gas-to-gasoline (16,000 bbl/d).

Our methanol-based technologies, plants and processes are cost effective and maximize production to increase profit margins.
Methanol processes

**Lurgi MegaMethanol™**

We have designed and built complete Steam Reforming units that are used in over 130 plants for H₂/CO applications and for methanol production at capacities of up to 2500 mtpd. In over 20 of our medium and large capacity Low Pressure (LP) and Lurgi MegaMethanol™ plants, our combined reforming technology minimizes effective syngas volumes. Our GigaMethanol process employs oxygen-blown autothermal reforming to achieve extremely high production capacities and unrivalled economies of scale.

**The Lurgi MegaMethanol™ 5,000 tpd Concept**

We developed our Lurgi MegaMethanol™ technology for world-scale methanol plants capable of producing more than one million metric tons of methanol a year. Achieving this sort of capacity requires a specially designed process with advanced, proven and reliable technology that enables cost-optimized energy efficiency and low environmental impact.
Oxygen-based technology enables large syngas capacities:

- High reforming pressure (e.g. enables smaller lines)
- Optimum stoichiometric number, no $\text{H}_2$ surplus
- Small syngas/recycle compressors

Two-stage synthesis reactor system:

- Low recycle ratio
- Reduced line/equipment sizes
- Low natural gas consumption
- Minimized investment cost for large scale plants

**Methanol Production using Combined Reforming**

1. Natural gas
2. Desulfurization
3. Steam-reforming
4. Autothermal reforming
5. Methanol synthesis
6. Methanol distillation
7. Air separation
8. Oxygen
9. Purge gas
10. Pure methanol
Syngas Production

The first step in methanol production is syngas generation. Air Liquide Global E&C Solutions offers a suite of technologies for making syngas, including steam methane reforming (SMR), combined reforming (CR) and oxygen-blown autothermal reforming (ATR). This broad spectrum of technologies enables Air Liquide Global E&C Solutions to provide the ideal facility for your needs, one that minimizes operational costs while maximizing efficiency. Since synthesis gas plant accounts for over 60% of the cost of methanol plant construction, its optimisation provides a substantial cost benefit.

Oxygen-blown natural gas reforming, either in combination with steam reforming or as pure autothermal reforming, is currently considered to be the best technology for large natural gas-based syngas plants.

- **Conventional Steam Methane Reforming**
  Conventional steam reforming is economically applied in small and medium-sized methanol plants, with a maximum single-train capacity of approximately 3000 mtpd, depending on the composition of your natural gas feedstock.

- **Combined Reforming**
  Combined reforming combines autothermal and steam reforming and is the most economic way to generate synthesis gas for methanol plants with capacities of 2,500 mtpd to 7,000 mtpd.

- **Autothermal Reforming**
  Pure autothermal reforming can be used to make syngas whenever light natural gas is available as feedstock, especially when capacities above 7,000 mtpd are required.
Methanol synthesis
The gas stream obtained from syngas production is then converted into methanol. Our reactors have a long and proven track record. They are available in single-stage water-cooled or two-stage water- and gas-cooled configurations that can be optimized by heat management or interstage condensation.

Methanol distillation
After synthesis, methanol undergoes energy-integrated distillation to produce high-purity methanol (e.g. grade AA and IMPCA grade). The crude methanol is purified in a cost-saving 2-column or an energy-saving 3-column distillation unit. The low boilers are removed in the pre-run column and the higher boiling components are separated in either one or two pure methanol columns.
Methanol-to-propylene

**Lurgi MTP™**

Over the last few decades, advances in chemical science have vastly expanded the use of propylene across a vast array of chemicals. Polymer-grade propylene is a feedstock for polyolefins, acrylates, methacrylates and acrylonitrile. Chemical-grade propylene is used for large commodities like oxo alcohols, propylene oxide and phenol.

The Lurgi MTP™ process combines an efficient reactor system and a very selective and stable zeolite-based catalyst.

To produce propylene, methanol is first fed to an adiabatic DME pre-reactor, where it is converted to dimethyl ether (DME) and water. The methanol-water-DME stream is then routed to the MTP reactor along with steam and recycled olefins, producing a propylene-rich mixture containing various hydrocarbons.

- Maximized polymere-grade propylene production
- Proprietary low coking zeolite catalyst
- Simple fixed-bed process
- In-situ regeneration
- Long catalyst life cycles
- Mild operating conditions (1.3 bar, 480°C)
- Ethylene co-production possible
- Feedstock independence
In order to keep catalyst reaction levels stable while ensuring maximum propylene yield, small streams of fresh feed from the DME pre-reactor are fed between the catalyst beds in the reactor. This is important for controlling the reactor’s overall temperature profile. The product mixture from the reactors is cooled and water is separated from product gas. The product gas is compressed and all traces of water, carbon dioxide, and DME are removed. From this purified gas, propylene is fractionated along with a small stream of ethylene, if and when required. Recycle streams that still contain olefins are returned to the main synthesis loop as additional sources of propylene.

Both the propylene and ethylene thus produced are polymer-grade. Lurgi MTP™ also generates MTP gasoline and MTP liquefied petroleum gas as co-products, adding value to the technology. Gasoline derived from Lurgi MTP™ is an ideal blending stock for any gasoline pool, because it is free of sulfur and has low benzene content and a high octane number.
Gas-to-gasoline

**G2G™ Technology**

**Innovating for cleaner and more efficient gasoline production**

Air Liquide Global E&C Solutions and ExxonMobil have a global technology licensing agreement to market and license Air Liquide’s proven Lurgi MegaMethanol™ technology combined with ExxonMobil’s proprietary methanol-to-gasoline (MTG) technology to transform natural gas into ultra-low sulfur gasoline.

The G2G™ technology transforms natural gas, as well as other feedstocks, into motor gasoline containing virtually no sulfur and low in benzene content. The integration of both Air Liquide Global E&C Solutions and ExxonMobil technologies into one combined solution will minimize project interfaces, off sites and logistics complexities, as well as overall investment for synthetic fuel production.

**An alternative to petroleum refining**

G2G™ technology is simple to operate and scalable from 2,500 to over 20,000 bbl/d, meeting the requirements for ASTM D4814 Specification for Automotive Spark-Ignition Engine Fuel.
- Minimal project interfaces
- Optimized off-sites and simpler logistics
- Lower capital investment
- Produces ultra-low sulfur and low-benzene gasoline
- Can be used as gasoline or blended with other refinery stocks
Diverse feedstocks for a broad range of plants

Air Liquide Global E&C Solutions is unique in being able to produce methanol from any feedstock, including coal, heavy hydrocarbons and natural gas, thus giving customers the flexibility of cost effective production aligned with feedstock availability.

Coal to syngas

Lurgi Fixed Bed Dry Bottom (FBDB) technology is particularly effective with low-rank coal, has low oxygen consumption and high gasification efficiency, rendering its use in large-scale applications beneficial both economically and in terms of environmental compliance.

Refinery hydrocarbons to syngas

With our multipurpose gasification MPG™ technology, heavy hydrocarbons can be used to make syngas. This technology is suitable for producing large quantities from the non-catalytic partial oxidation of solid, gaseous or liquid feedstock. It offers maximum feedstock flexibility, excellent safety and long burner and reactor lifetimes.

Natural gas to syngas

For natural gas to syngas production, customers can choose between our Steam Methane Reforming, Combined Reforming and Autothermal Reforming technologies. Such flexibility enables us to work closely with our customers to determine the best solution for their needs.
Lurgi MegaMethanol™ and Lurgi MTP™ References

<table>
<thead>
<tr>
<th>Year</th>
<th>Location</th>
<th>Company/Group</th>
<th>Technology</th>
<th>Feedstock</th>
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*Note: Tons per Year (tpy) indicates the production capacity of the respective facilities.*
Evolving with you

Continually stepping up our game

Air Liquide Global E&C Solutions’ innovative methanol production technologies (Low Pressure, Lurgi MegaMethanol™ and Lurgi Giga Methanol) and downstream technologies (G2G™ and Lurgi MTP™) enable a range of plant options designed to maximize your efficiency, improve the quality of your products and minimize your operating costs.

All of our plants are manufactured to the highest standards and are backed by over a century of experience.

Did you know?

The quality of the pure methanol produced at most Lurgi methanol plants exceeds grade AA, as per US federal specification O-M-232 J. The requirements for fuel grade methanol are less stringent, particularly when used as a blending component for gasoline. Lower methanol purity leads to savings in distillation energy demand and investment cost.
Air Liquide Global E&C Solutions

Together our people develop innovative technologies and equipment, delivering tomorrow’s process engineering solutions today, by:

• Delivering, on time and on cost, safe and reliable production units to Air Liquide Group and our Customers.

• Developing innovative technologies covering the entire engineering project life cycle to closely address our Customers’ needs and enable them to optimize the use of natural resources.

• Growing experts in the engineering and construction industry, reflecting the diversity of our markets and regions.
Safety and reliability

In the proud century-long tradition of the Air Liquide Group, safety and reliability are central to everything we do — for our employees and yours, and for the people who live and work near the plants we build.

We aspire to the highest safety standards in every project, as reflected in our very low incident rate.

Protecting the environment

We are committed to protecting the world we live in.

Each of our facilities meets local environmental standards. All of our technologies include system start-up and shut-down solutions that meet or exceed the most stringent legal requirements.

Our technologies are designed to minimize their impact on the environment.
Project Execution

Whether you are looking for a complete methanol production plant or new process components for an existing facility, we meet the same exacting standards for engineering, procurement and production.

Not only have we developed the technologies we offer, we also operate Air Liquide Group plants across the world. This gives our project management teams the skill and capacity to undertake feasibility studies, advise on process elements, facilitate permitting and licensing, interact with preferred suppliers of specialty chemicals, gases and equipment, and manage and supervise construction, installation, commissioning and start-up.

Our experience in methanol plant engineering and construction has given us the knowledge and expertise necessary to integrate a variety of other technologies, such as ammonia processing, and thus provide a complete solution, from design to construction.

This is what has made Air Liquide Global E&C Solutions a global leader in the development of methanol production.

You help make us smarter

At Air Liquide Global E&C Solutions, we make it a point to learn from our customers.

We and the Air Liquide Group use your operational experience to guide the research and development that enable us to find new and innovative solutions.
Air Liquide Global E&C Solutions is the world’s leading supplier of high-capacity methanol plants. Our expert project teams work closely with our customers to assess their needs and recommend the best solutions from among innovative and reliable Lurgi methanol technologies. Whether you need to produce 250 metric tons a day or 10,000, we can provide a complete and competitive solution.

Air Liquide and Lurgi

In 2007, Air Liquide acquired the German engineering group Lurgi, and with it over a century of experience developing processing technologies for oil refiners, energy producers and other industrial companies that need gases and related services. The result is an extensive portfolio of proprietary Air Liquide Global E&C Solutions technologies of proven efficiency and reliability.