

Low-carbon Hydrogen

An integrated technology solution for
large-scale hydrogen production



A woman wearing a white Air Liquide hard hat and safety glasses is looking upwards. She is wearing a red and dark blue work jacket with the Air Liquide logo. She is holding a black handheld device. The background is a large industrial facility with blue and white pipes and structures.

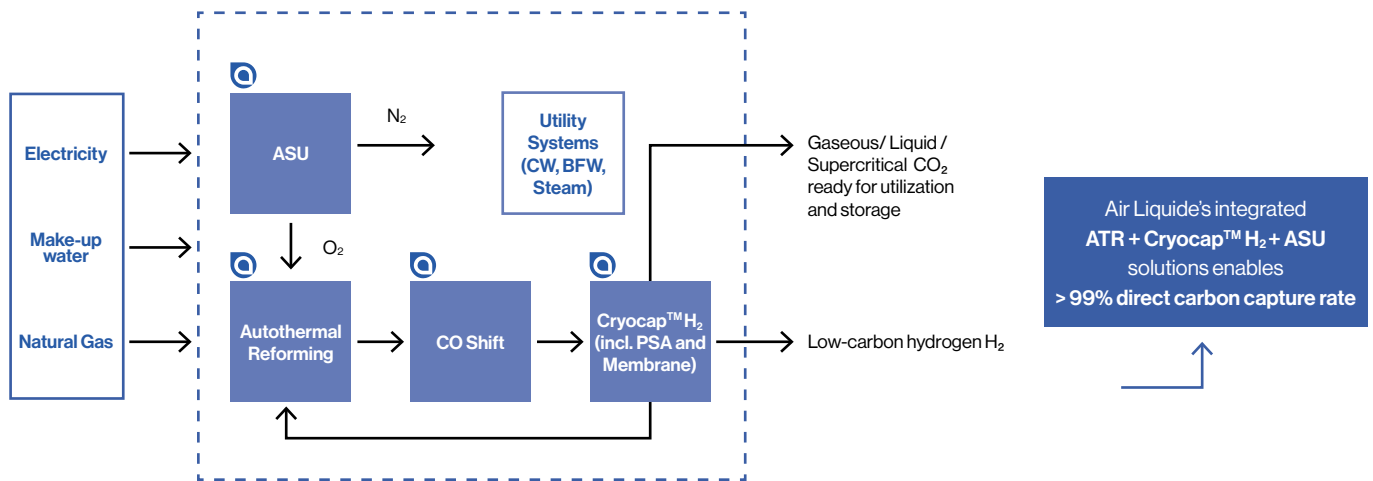
An integrated solution

We offer an integrated approach to the production of hydrogen, bringing together our proven technologies in autothermal reforming (ATR), cryogenic carbon capture (Cryocap™ H₂) and air separation units (ASU).

By combining these technologies, we achieve best-in-class low-carbon hydrogen production at a competitive cost and with a reduced capital investment. Our advanced carbon capture technology, capable of capturing over 99% of CO₂ emissions, enables maximized hydrogen yield with minimum carbon intensity.

Benefits of an integrated solution

Best integrated technology solution for low-carbon hydrogen



ATR + Cryocap™ H₂ + ASU, a differentiated, low-carbon technology approach that delivers:

Lowest Cost of Production

- Internal combustion in the ATR with oxygen replacing the need for fuel and flue gas treatment
- The process enables CO₂ to be readily available in different forms (gas, liquid, supercritical) with minimal cost variation

Lowest Capital Investment

- A single ATR reactor as an alternative to multi-train Steam Methane Reformers
- Maximum possible modularization for ASU
- Higher scope for modularization for Cryocap™ H₂ when compared to alternative capture technologies

Minimum Carbon Intensity

- More than 99% direct CO₂ capture rate due to minimum carbon loss
- Maximum H₂ yield leading to minimum with scope 3 emissions from supplied feedstock
- Integration potential with renewable electricity minimizing overall carbon intensity

A best-in-class solution combining world-class hydrogen production, CO₂ capture and oxygen production technologies

- Lurgi™ Autothermal Reformer (ATR)
- Cryocap™ H₂
- Air Separation (ASU)



Autothermal Reforming

Key Advantages:

- Cost-effective and scalable - utilizes a single reactor and burner system enabling a straight forward scale up
- Lower CapEx - partial combustion before reforming significantly reduces steam input for syngas generation
- High carbon capture efficiency - over 99% of CO₂ is inherently capturable, eliminating the need for post-combustion carbon capture from flue gas
- Large-scale hydrogen production - generates up to 1 million Nm³/h H₂, from a single reactor, enabling a fast track and impactful decarbonization
- Proven reliability - decades of experience using proprietary media-cooled burner design ensuring operational reliability



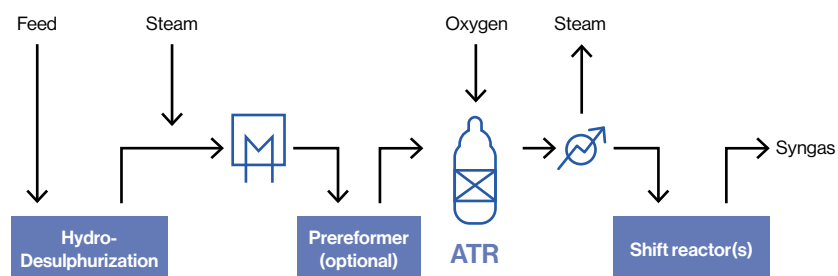
Best technology for large-scale hydrogen production

Air Liquide's Lurgi™ ATR technology delivers large-scale, low-carbon hydrogen production in a single train.

Its robust design, featuring proven refractory materials and a proprietary media-cooled burner, ensures optimal performance and reliability for large-scale applications.

The adaptability of the technology to various natural gas feed pressures and capacities, combined with its scalability and operational flexibility, aptly fits the need of energy transition.

With a proven track record and successful operation at capacities exceeding 500,000 Nm³/h of hydrogen, Lurgi™ ATR technology is enabling industry-wide decarbonization and capacity expansion.



ATR based smart syngas solution: Lurgi Megasynt™- applied since 2002

34

Industrial
References

6

Operating
References of size
> 500,000 Nm³/h H₂
syngas

>300

Syngas
generation
units delivered

70+

years of ATR
industrial
experience

0.5-1.5

Steam
to carbon ratio

Up to
80 barg

Operating
pressure possible

Cryocap™ H₂

Key Advantages:

- Proprietary membrane technology enables high purity product with maximum yield (>99% H₂ recovery) resulting in minimum NG consumption thereby minimal Scope 3 emissions
- Direct high-purity CO₂ output meeting the most stringent specifications- available in gaseous, liquid, or supercritical form for efficient transport with minimal energy use
- Purely electrically driven with best-in-class efficiency - enables maximum steam co-valorization from hydrogen plant
- Maximum carbon capture - smart recycling of unconverted CH₄ and CO to ATR minimizes carbon loss
- Superior reliability & availability - fully proven technology benefiting from > 9 years operation

>99 %

H₂ recovery
from Syngas

Down to

150

kWh/tCO₂
High energy
efficiency

~0

Steam
consumption

>99 %

CO₂ recovery

>99.9 %

CO₂ purity

Down to
<7 barg liquide
Up to

>190 barg

Flexible CO₂ state

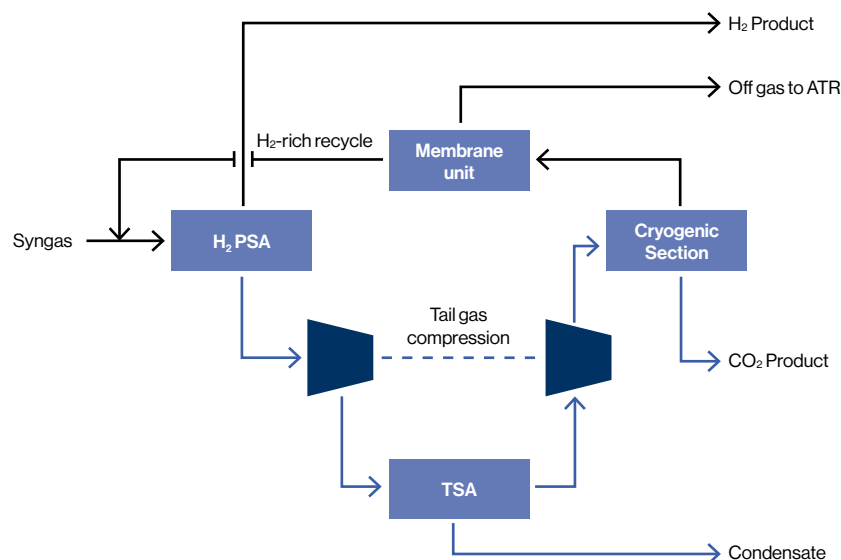
Industrially proven solution for CO₂ capture from hydrogen production

Air Liquide's Cryocap™ H₂ carbon capture technology is a perfect complement to the Lurgi™ ATR technology, as it is designed to treat large capacities of syngas, producing pure hydrogen for diverse uses and pure CO₂ for utilization or storage.

Cryocap™ H₂ inherently produces liquid or pressurized CO₂, thus CO₂ product compression and conditioning require less capital and operational expenditure than other CO₂ capture processes.

In addition, Cryocap™ H₂ remains in a leading position in terms of plot requirement and constructability.

Air Liquide is in the unique position of operating the one and only industrially demonstrated cryogenic CO₂ capture technology from hydrogen production - an Air Liquide facility that has been operating since 2015 in Port Jerome, France.



Air Separation

Key Advantages:

- Offering stick-built to fully modularized designs, adapted to specific project/customer requirements and performance needs
- Managing CapEx and OpEx to deliver optimal process efficiency
- Highly reliable design, enabling oxygen availability (more than 99%)
- Safe design for production of high purity oxygen at very high pressure with maximum energy efficiency
- Air Liquide capitalizes on its own real plant operational data, derived from decades of experience of industrial operation

>4000

Air Separation
Units built

~6000

MTPD O₂
Realized single
Train

~0

Power import with
ATR plant steam
integration

~250,000

MTPD
O₂ production
facility

>99.9 %

Realized O₂
purity

>120 barg

Realized O₂
supply pressure



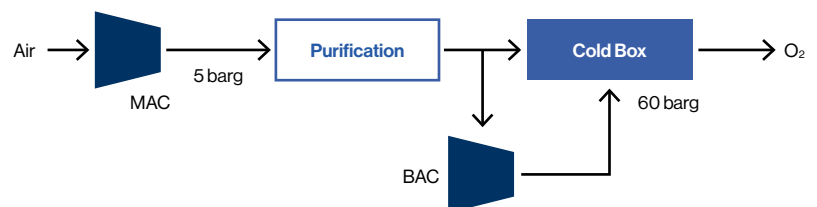
Leading Technology for large-scale oxygen production

Air Liquide has extensive experience in the design, engineering, construction and operation of ASU plants and is a world leader in the production and supply of industrial gases, with more than 550 plants worldwide with oxygen production capacity of approximately 250,000 metric tonnes per day (MTPD).

Air Liquide has also engineered and built over 4000 plants for third party customers.

Drawing on our own experience as an owner/operator and supplier of ASU plants, we design plants to achieve the best possible combination of price, power consumption, operating and maintenance costs and material quality.

Conventional MAC-BAC Process



SHARP Process



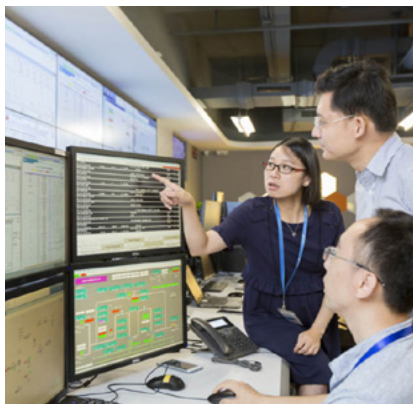
Air Liquide Engineering & Construction:

Your partner for any successful project model



Process Technology

Licensing engineering services
& proprietary equipment



Conceptual & Front-End Engineering Design

High-end engineering
& design capabilities



Integrated Solutions

Project management
& execution services





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