

# Low-carbon Hydrogen

An integrated technology solution for  
large-scale hydrogen production





A woman wearing a white Air Liquide hard hat and safety glasses, 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 metal structures and pipes.

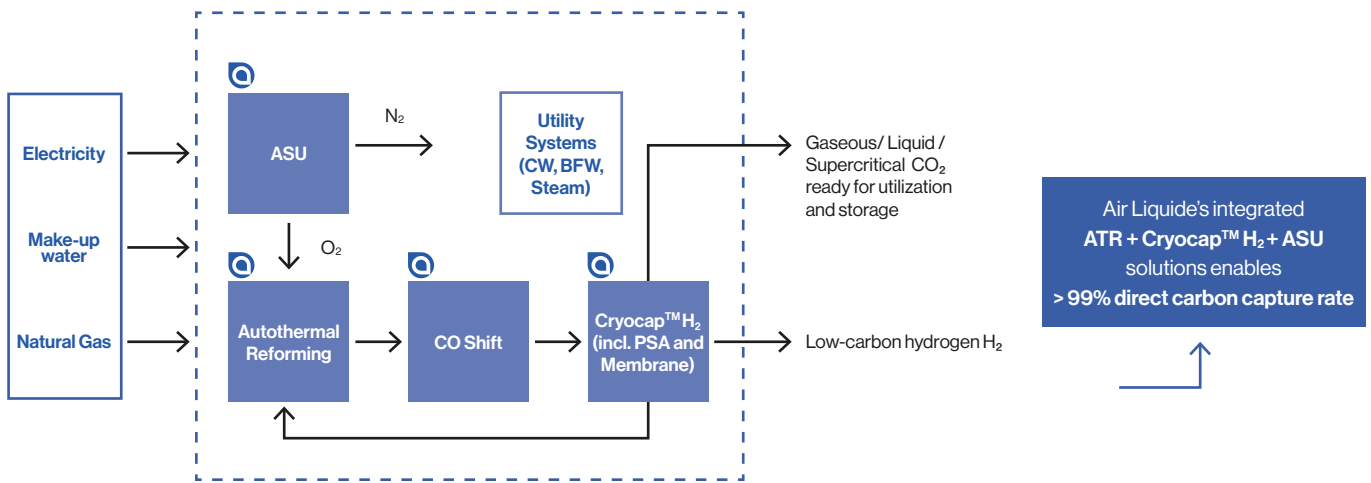
## An integrated solution

We offer an integrated approach to the production of hydrogen, bringing together our proven technologies in autothermal reforming (ATR), cryogenic carbon capture (Cryocap™ H<sub>2</sub>) 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 CO<sub>2</sub> emissions, enables maximized hydrogen yield with minimum carbon intensity.

# Benefits of an integrated solution

Best integrated technology solution for low-carbon hydrogen



## ATR + Cryocap™ H<sub>2</sub> + 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 CO<sub>2</sub> 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™ H<sub>2</sub> when compared to alternative capture technologies

### Minimum Carbon Intensity

- More than 99% direct CO<sub>2</sub> capture rate due to minimum carbon loss
- Maximum H<sub>2</sub> 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, CO<sub>2</sub> capture and oxygen production technologies**

- Lurgi™ Autothermal Reformer (ATR)
- Cryocap™ H<sub>2</sub>
- 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 CO<sub>2</sub> is inherently capturable, eliminating the need for post-combustion carbon capture from flue gas
- Large-scale hydrogen production - generates up to 1 million Nm<sup>3</sup>/h H<sub>2</sub>, 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

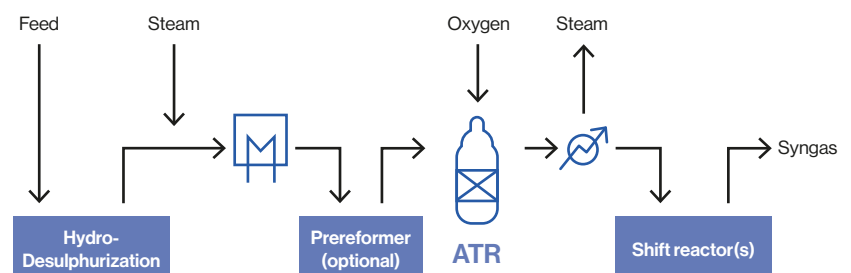
Air Liquide's Lurgi™ ATR technology delivers large-scale, low-carbon hydrogen production in a single train.

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 Nm<sup>3</sup>/h of hydrogen, Lurgi™ ATR technology is enabling industry-wide decarbonization and capacity expansion.

34 Industrial References	6 Operating References of size > 500,000 Nm <sup>3</sup> /h H <sub>2</sub> 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



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

# Cryocap™ H<sub>2</sub>

## Key Advantages:

- Proprietary membrane technology enables high purity product with maximum yield (>99% H<sub>2</sub> recovery) resulting in minimum NG consumption thereby minimal Scope 3 emissions
- Direct high-purity CO<sub>2</sub> 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 CH<sub>4</sub> and CO to ATR minimizes carbon loss
- Superior reliability & availability - fully proven technology benefiting from > 9 years operation

>99 %

H<sub>2</sub> recovery from Syngas

Down to

150

kWh/tCO<sub>2</sub>  
High energy efficiency

~0

Steam consumption

>99 %

CO<sub>2</sub> recovery

>99.9 %

CO<sub>2</sub> purity

Down to  
<7 barg liquide  
Up to

>190 barg

Flexible CO<sub>2</sub> state



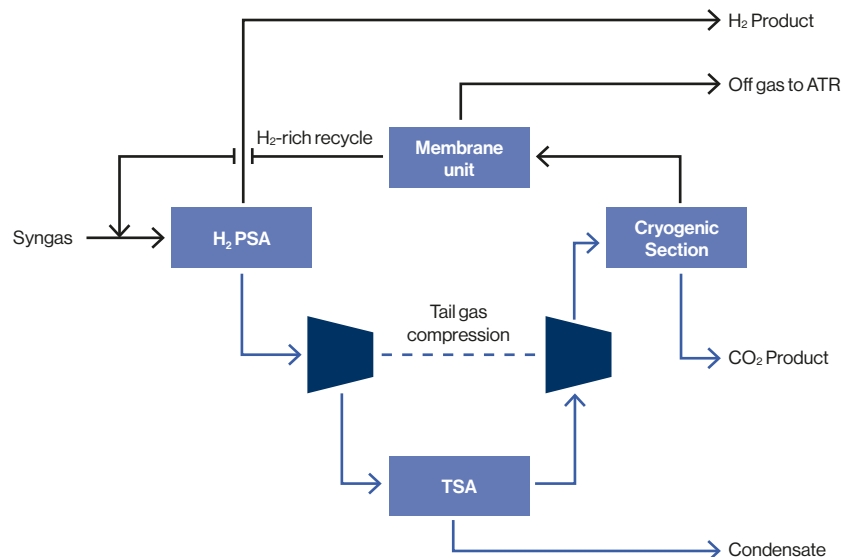
## Industrially proven solution for CO<sub>2</sub> capture from hydrogen production

Air Liquide's Cryocap™ H<sub>2</sub> 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 CO<sub>2</sub> for utilization or storage.

Cryocap™ H<sub>2</sub> inherently produces liquid or pressurized CO<sub>2</sub>, thus CO<sub>2</sub> product compression and conditioning require less capital and operational expenditure than other CO<sub>2</sub> capture processes.

In addition, Cryocap™ H<sub>2</sub> 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 CO<sub>2</sub> 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



## Leading Technology for large-scale oxygen production

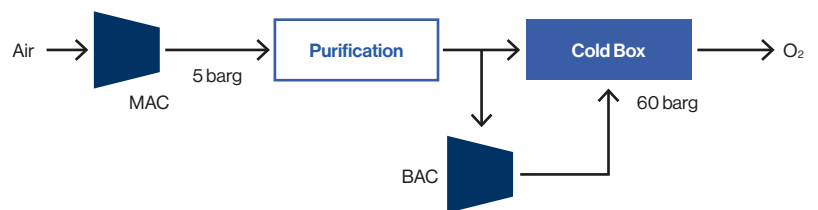
Air Liquide has extensive experience in the design, engineering, construction and operation of ASU plants and is a world leader in the production and supply of industrial gases, with more than 550 plants worldwide with oxygen production capacity of approximately 250,000 metric tonnes per day (MTPD).

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.

>4000 Air Separation Units built	~6000 MTPD O <sub>2</sub> Realized single Train
~0 Power import with ATR plant steam integration	~250,000 MTPD O <sub>2</sub> production facility
>99.9% Realized O <sub>2</sub> purity	>120 barg Realized O <sub>2</sub> supply pressure

### Conventional MAC-BAC Process



### SHARP Process



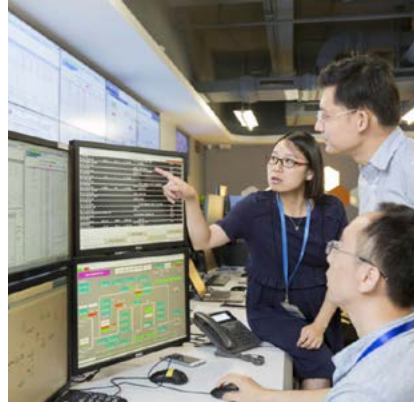
# Air Liquide Engineering & Construction:

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





**Contact us**

[hydrogen-syngas@airliquide.com](mailto:hydrogen-syngas@airliquide.com)

[www.engineering.airliquide.com](http://www.engineering.airliquide.com)