Air Liquide

& Hydrogen industrial merchant

V.Maldonato

AL-IM-WBL March 2012

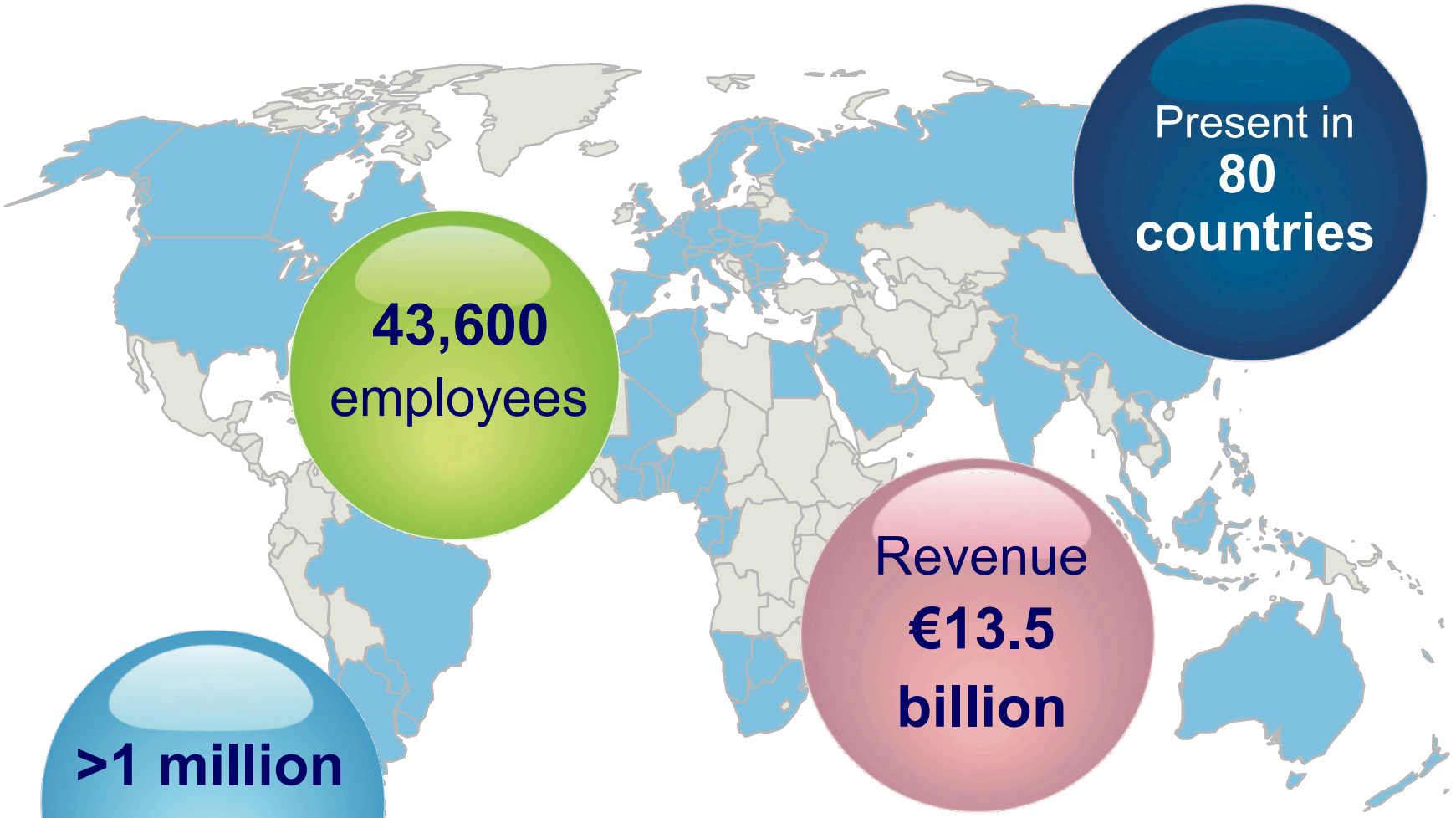
Content

- Air Liquide, Group **introduction**

- Air Liquide **industrial** hydrogen business
  - Production
  - Distribution
  - Customer installations & applications

- Air Liquide **new challenges with hydrogen energy** markets

Air Liquide Group: **Key Figures**



Air Liquide, the **world leader** in gases for industry, health and the environment

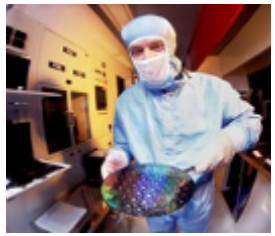
Air Liquide Group : **Ambitions**

- **42% of Air Liquide's revenue comes from gas applications which preserve life and the environment**
- **60% of Air Liquide's R&D budget devoted to developing technologies designed to sustainable development**
- **5 strategic pillars for growth**


Energy


Environment


Health


High-Tech


Developing economies

Air Liquide, the **world leader** in gases for industry, health and the environment

Content

- Air Liquide, Group **introduction**
- Air Liquide **industrial** hydrogen business
  - Production
  - Distribution
  - Customer installations & applications
- Air Liquide **new challenges with hydrogen energy** markets

Air Liquide & **hydrogen**

Background

- >40 years in industry applications
- >10 years in H2 Fuel cells

Expertise

- Engineering activities
- production, transport & distribution

Worldwide infrastructure

- > 200 hydrogen production units, including 38 large capacity units
- 1,800 km pipeline in Europe, the United States and Asia
- > 1,000 trucks

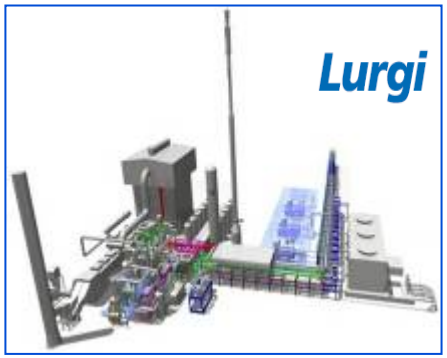
Sales

- 1,4 billion Euros in 2010
- 9 billion m3 produced by AL

More than 40 years of experience in hydrogen

AIR LIQUIDE

Production



Distribution

Application

Hydrogen merchant **sources : traditional ways**

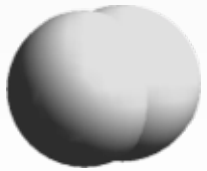
- **Principle overview : Raw materials + Energy -> H2 (+ by-products).**
- **Raw materials: Mainly hydrocarbons, coal and water.**
- **Sources of energy: Electricity and hydrocarbons.**

H2 Production

“On purpose”

H2 By-product

Hydrogen



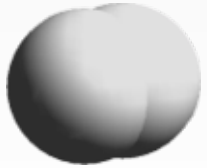
Hydrogen merchant **sources**

H2 Production

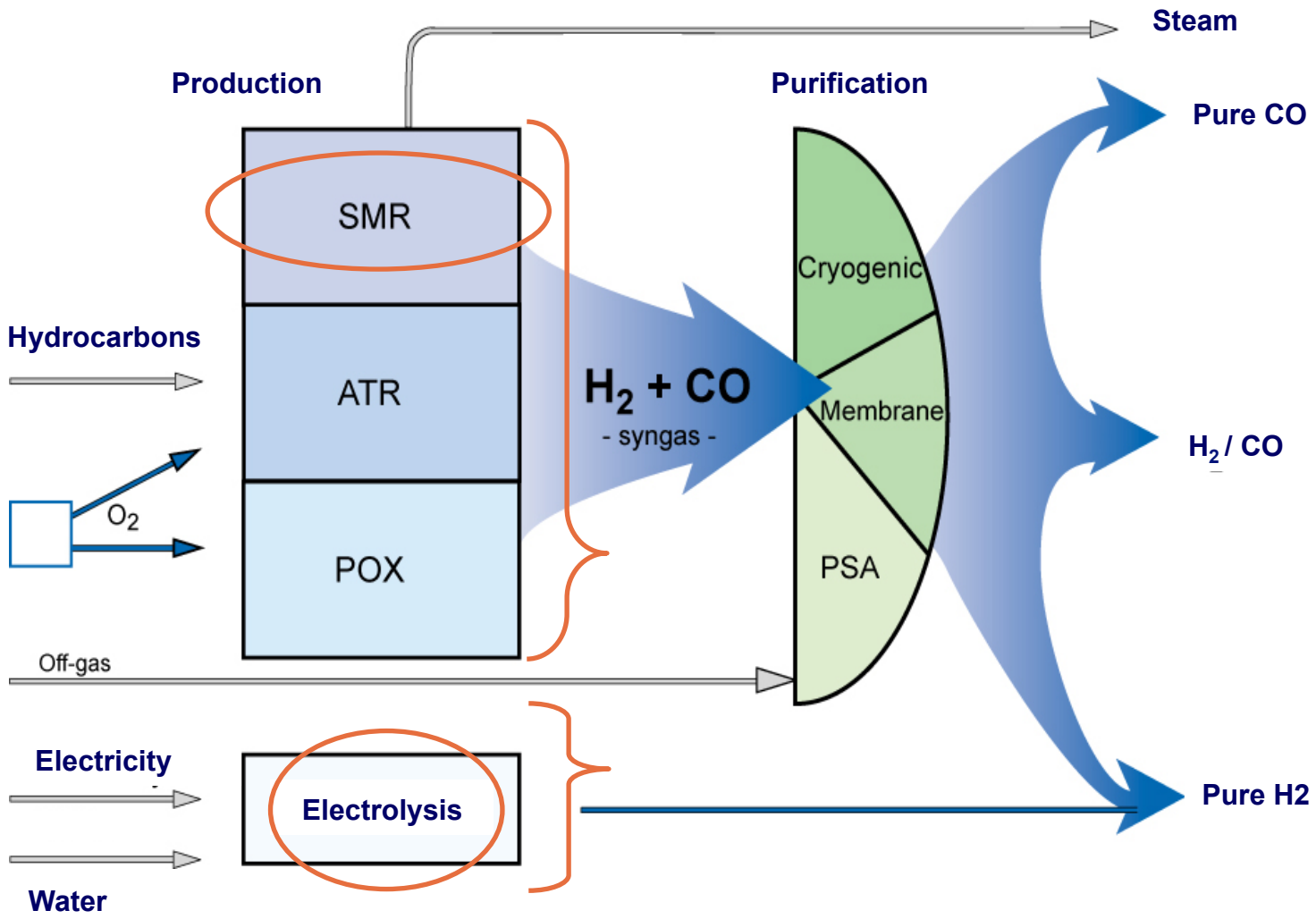
“On purpose”

H2 By-product

Hydrogen



Hydrogen production : main current processes

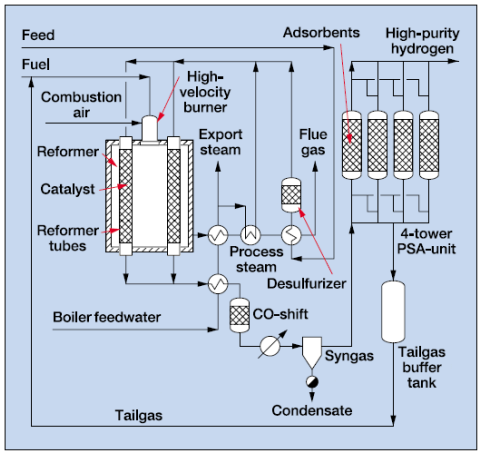


SMR: Steam Methane Reformer
POX: Partial Oxydation

ATR: Auto Thermal Reformer
PSA: Pressure Swing Adsorption

Hydrogen production : SMR

Principle of STEAM METHANE REFORMING (SMR)



$CH_4 + H_2O + Heat = CO + 3H_2$ (Reforming of methane)

$CO + H_2O = CO_2 + H_2 + Heat$ (Water gas shift)

SMR principle : step by step

Up to 130 000 m3/h

50 to 1000 m3/h

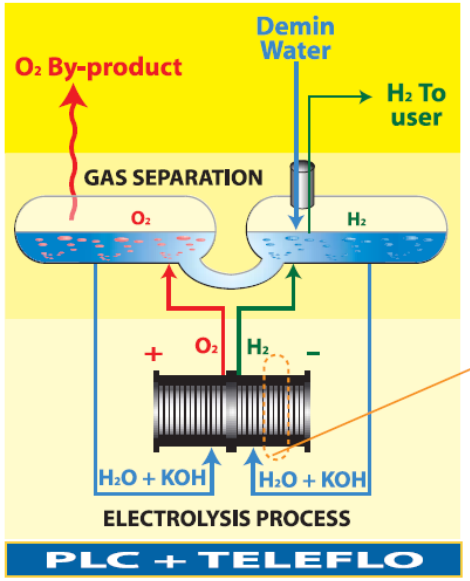
Large Industry Business:
On-Site SMR operated by AL for customer supply

Industrial Merchant Business:
H2 sourced from LI SMR

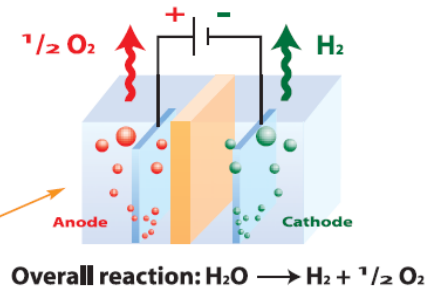
Industrial Merchant Business:
Hyos-R for customer supply

Hydrogen production : water electrolysis

- Electrolysis principle:



Demineralised water is fed into the HYOS. Within the electrolysis module, water is split into its basic elements when DC current is applied :



Hydrogen and oxygen bubbles are carried along with the electrolyte (KOH) to the gas separators. Finally, gaseous hydrogen is filtered and delivered to customer process.

- Overall reaction: H2O -> H2 + 1/2 O2

On-Site Electrolyser (HYOS-E)
for customer supply by AL
Up to 120 Nm3/h

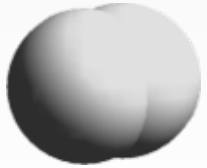
Hydrogen merchant **sources**

H2 Production

“On purpose”

H2 By-product

Hydrogen



Hydrogen by-product

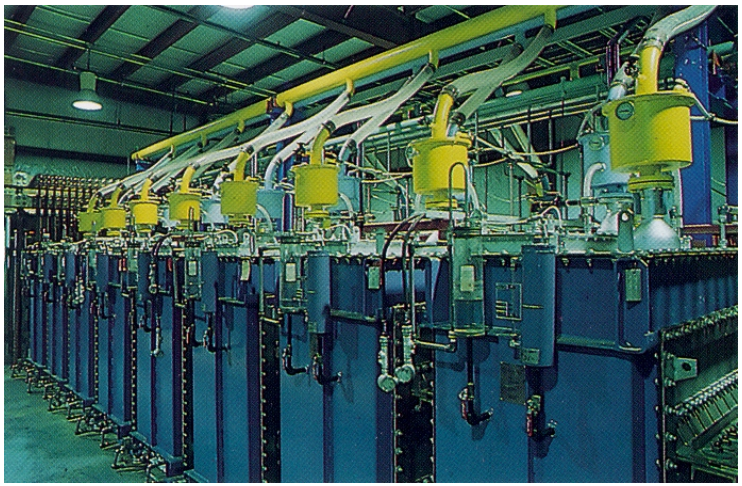
- H2 by-product = produced inadvertantly as a by-product of a process (chemical, petrochemical sources).
- H2 Offgas streams often vented or burned for fuel value instead of being valorized
- Chemical by-product sources are preferred (low cost, continuity of operation, relative good purity).
  - Ex : production of chlorine, sodium chlorate, ethylene, acetylene, cyanide, styrene, …
- Purification (PSA) needed to produce high quality H2

Hydrogen as a by-product of Chlorine production:

Principle:

$2\ Na\ Cl + 2\ H_2O \rightarrow Cl_2 + 2\ Na\ OH + H_2$

H2 sourced from third-party Electrolysis

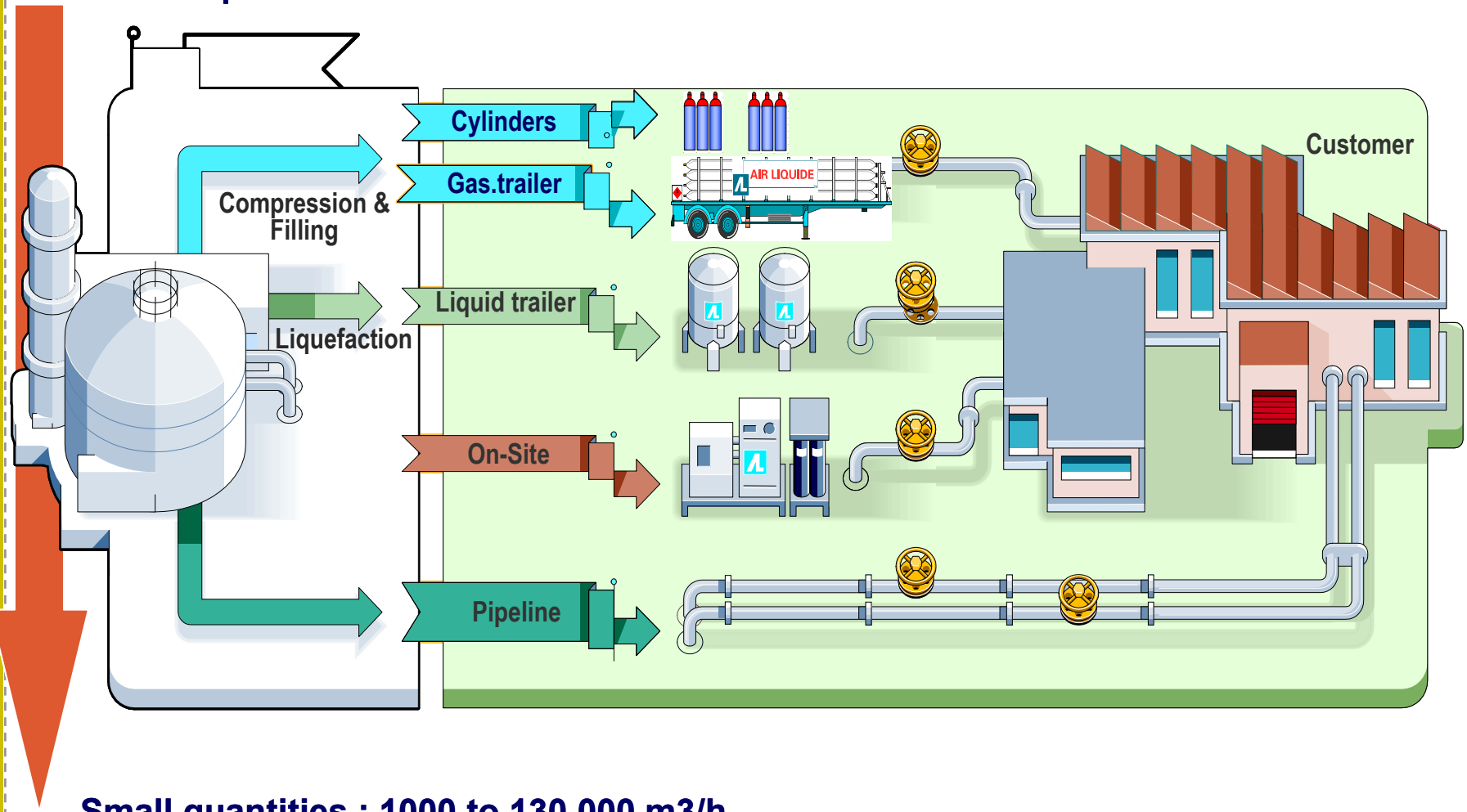


Content

- Air Liquide, Group **introduction**
- Air Liquide **industrial** hydrogen business
  - Production
  - Distribution
  - Customer installations & applications
- Air Liquide **new challenges with hydrogen energy** markets

Hydrogen distribution

Small quantities : 1 to 50 m3/h



Small quantities : 1000 to 130 000 m3/h

Hydrogen distribution

Cylinders

200 bars, 10 m^3 GH_2

Trucks - Trailers

Liquid : Cryogenic tanks

-253°C 40,000 Nm3

Gaseous : Trailers

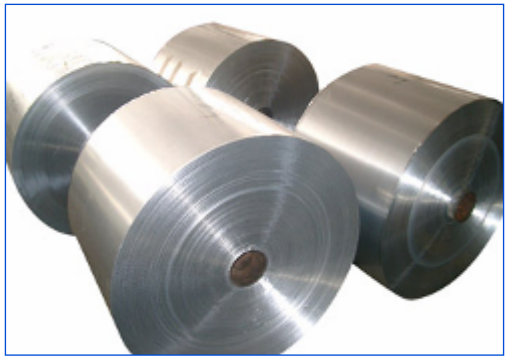
200b steel (4000 m3)

200b composite (6300 Nm3)

Pipeline

12 networks worldwide

Many existing applications for H_2 …



Heat Treatment

10 m3/h (batch) –
1000 m3/h (continuous)

Chemicals & Reffinery

Ex: 0,067 t/ton Anilin

Petroleum refining
(desulfuration & hydrocracking)

10-100 km3/h

Glass
80 to 500 m3/h

Ariane 5
28 t/launch

H2 Ultra pure <1ppb
50 to 500 m3/h

Future

Fuel cell vehicle
1 kg for 100 km

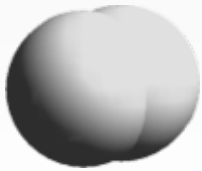
Content

- Air Liquide, Group **introduction**
- Air Liquide **industrial** hydrogen business
  - Production
  - Distribution
  - Customer installations & applications
- Air Liquide **new challenges with hydrogen energy** markets

Transition from industrial H_2 to Hydrogen-Energy

- **A new application** : Hydrogen as an energy vector

Hydrogen → **Electricity**



⇨ **New opportunities and new challenges**

Sourcing / Production	Compression / Liquefaction	Distribution	Storage & installations	Applications

Key challenges regarding production

- Carbon-free processes : **BLUE Hydrogen**
- Competitiveness (production costs €/kg H2)
- High efficiency (energy/feedstock required / kg H2 produced)
- Production capacity : Industrial scale

How to transition towards a new energy mix?

- Air Liquide's **Blue Hydrogen** program

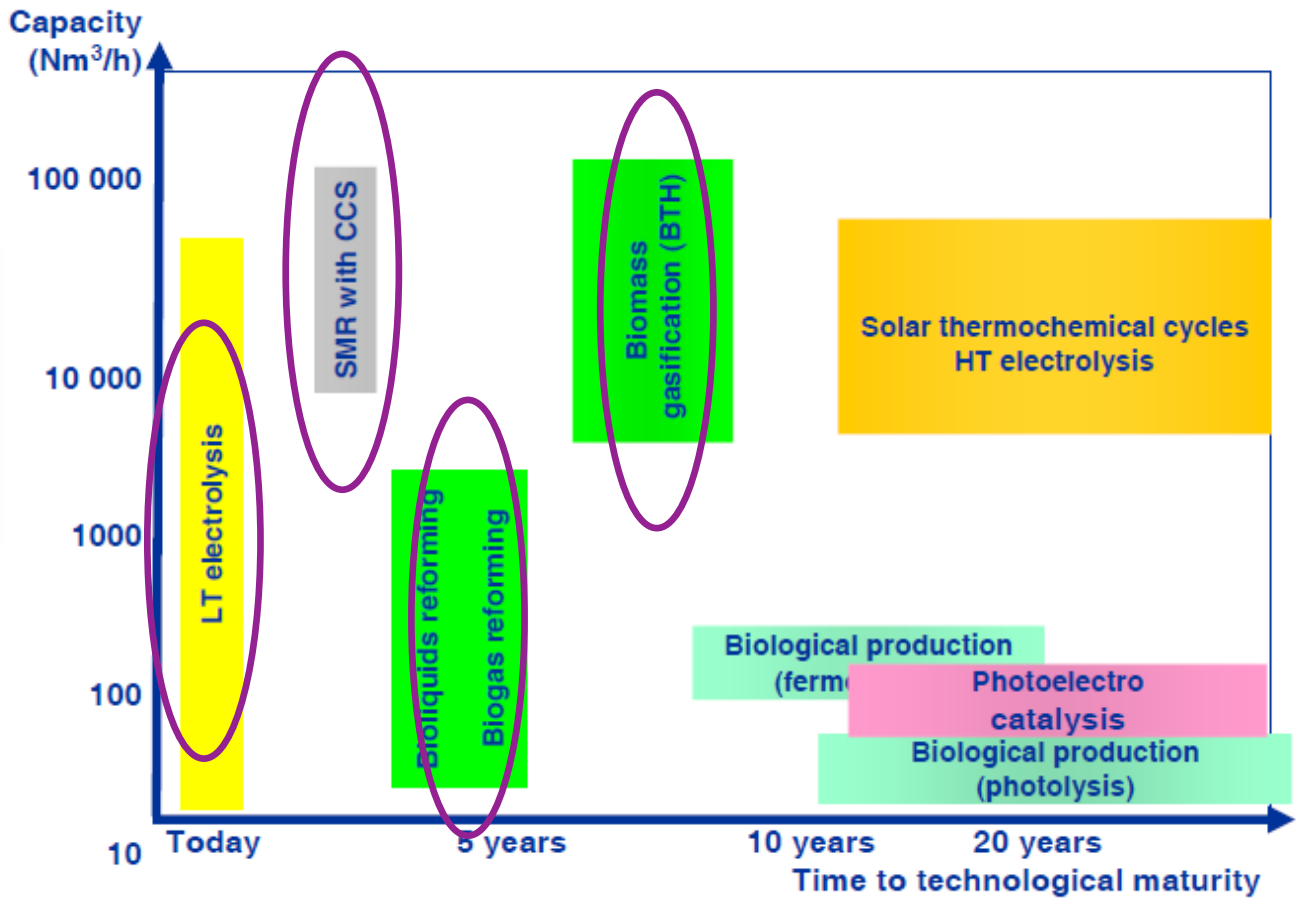
At least 50% of hydrogen energy produced through carbon-free processes by 2020

- renewable energy sources, water electrolysis and biogas reforming,
- carbon capture and storage technologies with natural gas reforming

- A commitment to meet both environmental requirements and social and economic constraints.

Hydrogen Production without CO_2 emissions

Vision on lean-CO_2 and renewable H_2 production technologies



Blue Hydrogen: Air Liquide commitment to decarbonize H2 production

Goals : Prepare H2 for tomorrow energy economy

AIR LIQUIDE

Today…we have strength

Industrial infrastructures & competencies

Prototype technologies

Demonstration projects & challenges

Costs

Rules, Standards & codes, Social Acceptance

Through Early Markets

Off-Grid

Backup

Specialty vehicles

Mobile generators

… Tomorrow, a sustainable energy for:

Transportation applications

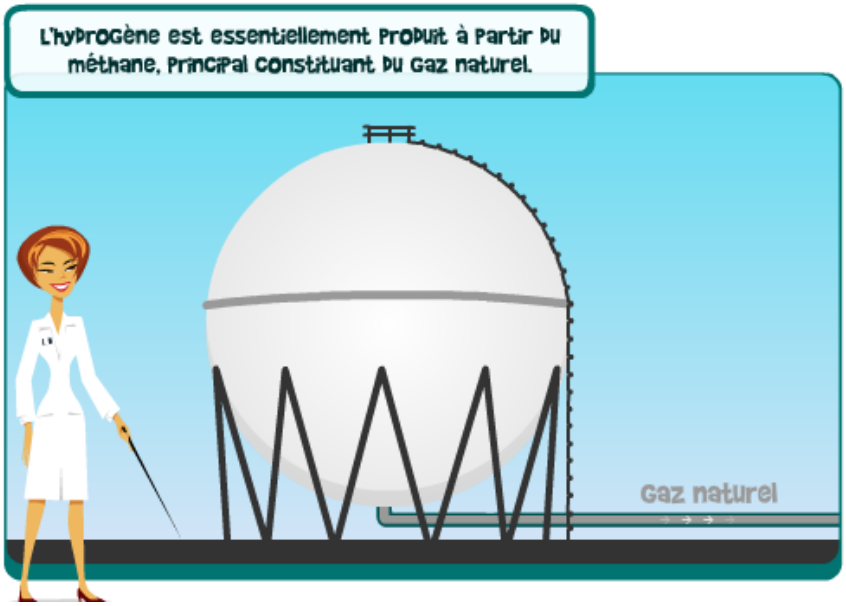
Stationary

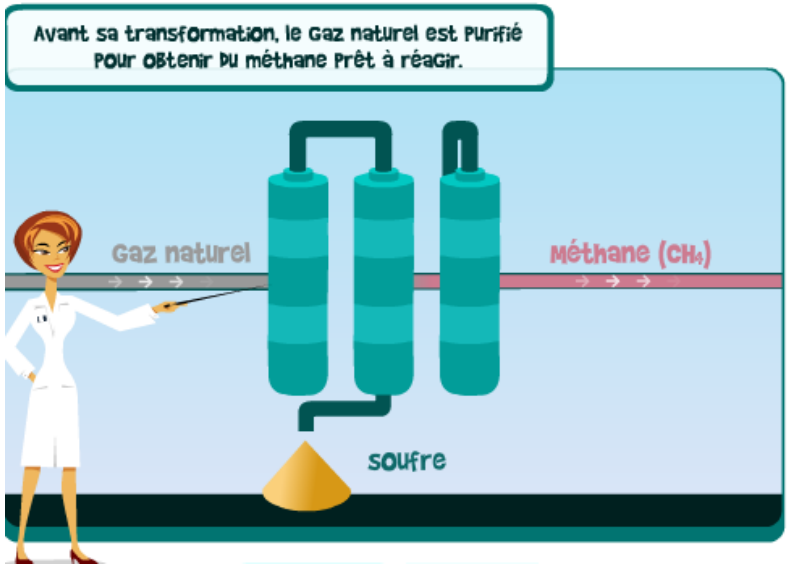
- With
  - Less CO_2 emission
  - Less dependency to fossil energy

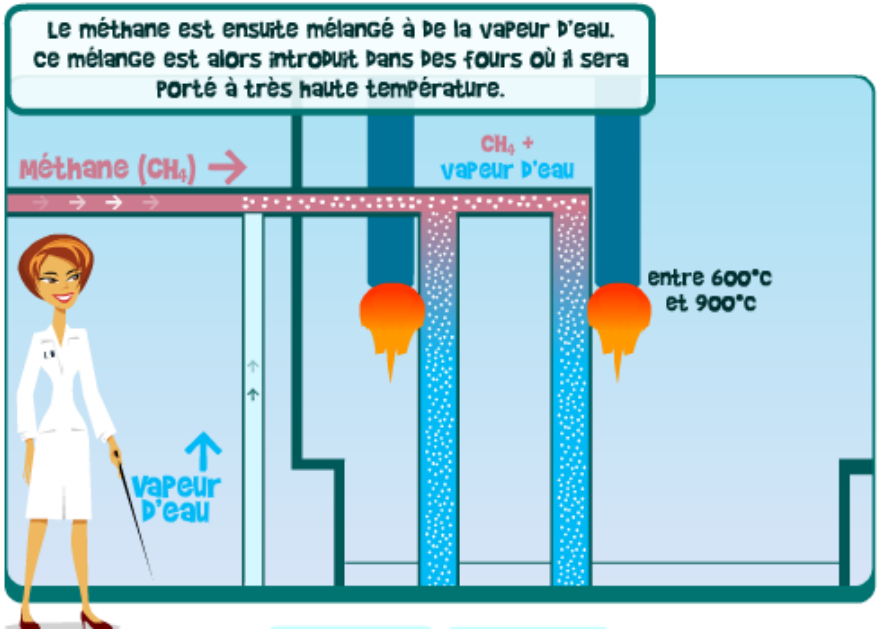
Thank you for your attention!

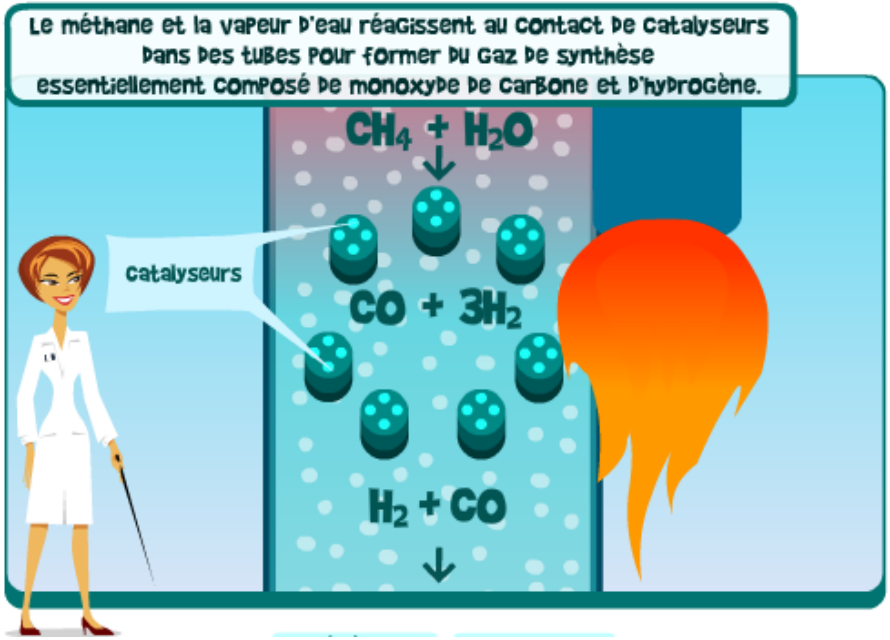
Back up

SMR principle : step by step









d

SMR principle : step by step