

Production, transport and handling of LH₂: Safety issues and knowledge gaps Laurence Bernard Simon Jallais

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Hydrogen mobility markets: Ready to scale TODAY

Paris :

- 150 H₂ Taxis HYPE
- 4 H₂ stations







Air Liquide already started to invest







Mobility

Germany

11 HRS

for Consumers

Π.

Power to Gas

+ 1 Electrolyze

Denmark

5 HRS



Mobility for Consumers California 4 HRS



Mobility for Consumers Japan 6 HRS







Mobility for Consumers Korea 1 HRS



Mobility for Consumers Paris, Brussels and Rotterdam 6 HRS

14 bn m³/yr

1,850 km H₂ pipelines

46 large H₂ plants

40 electrolyzers in operation

2 bn € sales / yr

120 H_2 stations installed by AL in the world

60 stations invested and operated by AL

Why Liquid Hydrogen ?

Higher density ⇒ Improved logistic and allow higher throughput



Lower foot print (factor 2) for car refueling stations

Synergies with others applications : planes, trucks, trains, boats, ...

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Low carbon H₂ pathways



"Large scale" liquefiers in operation (from 1960 to now)



2018 : AirGas (AL) 10 tpd - Calvert City, KY Hydrogen United 10 tpd - Charleston, TN

Europe :

Air Products Linde

Air Liquide

5 tpd - Rozenburg NL 4 tpd - Ingolstadt GE 6 tpd - Leuna GE 10 tpd - Waziers FR 2 tpd - Kourou - Guyana

Liquefiers announcements : an amazing acceleration end 2018

AIR LIQUIDE	Nov 2018	30 tpd	McCarran, Nevada
	Fev 2019	20 MW PEM (8t/d)	Becancour, Canada
AIR PRODUCTS	Sept 2018	30 tpd	La Porte, Texas
	Janv 2019	XX tpd	California
PRAXAIR	Nov 2018	30 tpd	La Porte, Texas
LINDE	Oct 2018	10 tpd	Leuna, Germany



Few words about LH₂ storages :





HySTRA Pilot 1250 $m^3 = 90 t$



Small carrier 2500 $m^3 = 180 t$

Laurence Bernard / Simon Jallais $9000 \text{ m}^3 = 640 \text{ t}$



Large carrier 160 000 $m^3 = 11 400 t$

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Safety issues and knowledge gaps $(\frac{1}{3})$

In the framework of the PRESLHy (FCHJU) project :

- State of the art analysis on LH₂ hazards (public report, see PRESLHy website)
 - WP3 : Release and mixing phenomena
 - WP4 : Ignition phenomena
 - WP5 : Combustion phenomena

• PIRT (Phenomena Identification Ranking Table) (public report)

- Definition of 43 physical phenomenas
- For each phenomena, the 24 experts (RPW Buxton 2018) gave a score between 1 to 5 regarding :
 - General level of understanding
 - Level of maturity of engineering modelling
 - Level of maturity of CFD modelling
 - Availability of experimental data
 - Criticality for enabling LH₂ in populated areas
- Calculations of knowledge and criticality scores
- Ranking of the R&D priorities



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Safety issues and knowledge gaps (2/3)

WP3 Priorities :

- 1. Medium pressure two-phase flashing releases
- 2. Supercritical high pressure releases
- 3. Pool vaporisation

WP4 Priorities :

- 1. Effect of cold T° on flammability limits (3 directions) and Minimum Ignition Energies
- 2. Electrostatic ignition
- 3. Solid oxygen / liquid hydrogen mixture formation & ignition

WP5 Priorities :

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- 1. Deflagration, Flame Acceleration, Deflagration to Detonation Transition and Detonation in presence of obstacles (confined and unconfined)
- 2. Rapid Phase Transition & BLEVE
- 3. Jet and pool fires

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Safety issues and knowledge gaps (3/3)

Both projects SH2IFT and PRESLHY will address these knowledge gaps through experiments and modelling that will be presented to you today.



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