Hydrogen and Fuel Cell Research Challenges and Opportunities – An Industrial Perspective

Live Workshop

25 February 2021 11:00-15:30 (GMT)

Follow us on LinkedIn, Twitter @H2FCSupergen and YouTube
Professor Nigel Brandon

Director, H2FC Supergen Hub
Dean of Engineering
Imperial College London
Professor John Irvine
Professor of Chemistry
St Andrew’s University
Session 2 – Green Hydrogen and Ammonia Production

25 February 13:45-15:30 (GMT)

http://www.h2fcsupergen.com/uncategorised/h2fc-workshop-hydrogen-fuel-cell-research-challenges opportuni...
Green Hydrogen and Ammonia Production

Challenges and opportunities

John T. S. Irvine

University of St Andrews
Contents

• Renewables

• Hydrogen Production and Electrolysis

• Ammonia

• CO₂ and co-electrolysis

• Solid Oxide Cells
Saipem 7000 marks the start of offshore work on the Neart na Gaoithe (NnG) wind farm, August 2020

- Owned by EDF Renewables and ESB
- 15 km off the Fife coast
- 54 turbines

2023
- Power 375,000 homes
- 450 megawatts

https://ocean-energyresources.com/
Zero Emission Train Project

Hydrogen Fuel Cell Electric Trains
Our decarbonised rail network in Scotland, 2035

- Electrified network; some 1,622 of single track kilometres to be electrified. Sections of route may include discontinuous electrification and the use of battery/electric bi mode trains, e.g. the Fife Circle.

- Alternative traction – transition solution (i.e. the use of alternative technology prior to electrification).

- Alternative traction – permanent solution (i.e. the use of battery and/or Hydrogen traction).

Rail Decarbonisation Plan launched at the end of **July 2020**. Decarbonisation of the rail network by 2035. First market engagement by **September 2020**
Alternative hydrogen carriers

• Ammonia
• Methane
• Hydrocarbons
• Diesel
• Ammonia is one of the most important industrial chemicals
• Widely used in agriculture as a fertiliser for food production.
• Conventionally ammonia is produced at very large scale utilising fossil energy sources
• Historically produced utilising hydrogen produced from Hydro power.
HISTORICAL LARGE SCALE PLANTS

- Two largest electrolyser plants worldwide
- Capacity: 30 000 Nm³/h each
- Energy consumption: approximately 135 MW each
- Supplied by renewable hydro power

Rjukan, Norway; 1927 – 1970’s

Glomfjord, Norway; 1953 – 1991
Redundancy of SMR plants

- Hydrogen £2400 per tonne
- Ammonia £170 per tonne
  - ie £680 per tonne $H_2$

- So why buy hydrogen when ammonia cracking cheaper 1/3 price
Wind and ammonia

http://freedomfertilizer.com/
Haber-Bosh Process

Main applications

High temperatures (400–500 °C)
High pressures (150–200 atm)

$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g) \quad \Delta H = -92 \text{ kJ mol}^{-1}$

Alternative energy-saving pathway?
Protonic ceramic conductors

With H₂ proton source

N₂ + 6H⁺ + 6e⁻ → 2NH₃

H₂ → 3H₂ → 6H⁺ + 6e⁻

With H₂O proton source

N₂ + 6H⁺ + 6e⁻ → 2NH₃

H₂O, O₂ → 3/2O₂ + 6H⁺ + 6e⁻

Competing mechanisms

H⁺ + e⁻ + * ⇌ *H (1)

N₂ + * ⇌ *N₂ (2)

H⁺ + e⁻ + *N₂ ⇌ *N₂H (3)

H⁺ + e⁻ + *H ⇌ H₂ + * (4)
Solid Oxide Electrolysis

\[ \Delta H = \Delta G + T \Delta S \]

\[ \text{H}_2\text{O} \rightarrow \text{H}_2 + \frac{1}{2}\text{O}_2 \]

\[ \Delta H = 285.8 \text{ kJ/mol at } 25^{\circ}\text{C} \]

\[ \Delta G = -zEF = -2EF. \]
The 3 modes of HTSE

• Thermoneutral:
  • Joule heating = heat consumed by the endothermic reaction
  • Electrical-to-chemical efficiency = 100 %

• Exothermic:
  • Joule heating > heat consumed by the endothermic reaction
  • Electrical-to-chemical efficiency < 100 %

• Endothermic:
  • Joule heating < heat consumed by the endothermic reaction
  • External heat source required
  • Electrical-to-chemical efficiency > 100 %

• External heat source examples:
  • Solar Thermal, Biomass
CO₂ electrolysis

Schematic of SOEC used for high temperature electrolysis

CO₂ + 2e⁻ → CO + O²⁻

O²⁻ → 1/2 O₂ + 2e⁻
In recent years, CO$_2$ electrolysis by SOEC have received increasing interest due to its potential rewards both in energy and environmental aspects.

- Renewable sources utilization as energy input
- High temperature operation reduces electricity demand, and offers fast electrode kinetics
- ‘Borrow’ materials and techniques from solid oxide fuel cells (SOFCs)
- Helps to address the issue of global warming

Thermodynamics of CO$_2$ electrolysis

Danish 2050 model
Green gas system linked to SOFCs and SOECs

- Increased use of methane and “green” gases
- SOEC can produce methane to the gas system when electricity prices are low
- Possibilities for storage of heat and gas help prevent overflow and deficiency in the electricity system
- High prices: SOFC production of electricity and heat
- Low prices: SOEC production of methane
Enhancing CO$_2$ electrolysis through synergistic control of non-stoichiometry and doping to tune cathode surface structures

L.Ye, M. Zhang, P. Huang, G. Guo, M. Hong, C. Li, J.T.S. Irvine, Kui Xie
Fujian Institute of Research on the Structure of Matter

Nat. Comm. DOI: 10.1038/ncomms14785
Exsolution

1 phase $\rightarrow$ 2 phases

Liquid

Alkali Feldspar Solid Solution + Liquid

Alkali Feldspar Solid Solution

2 Feldspars

https://www.tulane.edu/~sanelson/images/phdfig4.gif
Redox Exsolution

Emergent

Near Equilibrium
Manipulate perovskite stoichiometry for CO$_2$ Electrolysis

Oxygen Excess – interstitial oxide
B-site doped
A site deficient Ni doped-Emergent nanoparticles

- $\text{La}_{0.2}\text{Sr}_{0.8}\text{Ti}_{1.0}\text{O}_{3+\delta} - \text{LST}_{\text{O}^+}$
- $\text{La}_{0.2}\text{Sr}_{0.8}\text{Ti}_{0.9}\text{Cr}_{0.1}\text{O}_{3+\delta} - \text{LSTC}_{\text{O}^+}$
- $\text{La}_{0.2}\text{Sr}_{0.8}\text{Ti}_{0.9}\text{Mn}_{0.1}\text{O}_{3+\delta} - \text{LSTM}_{\text{O}^+}$
- $(\text{La}_{0.2}\text{Sr}_{0.8})_{0.95}\text{Ti}_{0.85}\text{Cr}_{0.1}\text{Ni}_{0.05}\text{O}_{3+\delta} - \text{LSTCN}_{\text{A}^-}$
- $(\text{La}_{0.2}\text{Sr}_{0.8})_{0.95}\text{Ti}_{0.85}\text{Mn}_{0.1}\text{Ni}_{0.05}\text{O}_{3+\delta} - \text{LSTMN}_{\text{A}^-}$
CO$_2$ electrolysis. (a) I-V curves at 800$^\circ$C; (b) short-term performances; (c) CO production (d) current efficiency with different cathodes.
Ni doped MnO
I-V curves of three system samples measured in CO$_2$ atmosphere at 800 °C

Reduced Ni/11%MnO$_x$ samples

FT-IR spectroscopy of CO$_2$ molecule absorbed on different reduced samples at 800°C

Cu/Ni doped CeO$_2$
CO$_2$ electrolysis at 800°C on Cu/Ni doped ceria

Reduced Ce$_{0.9}$(Cu$_{0.25}$Ni$_{0.75}$)$_{0.1}$O$_{2-\delta}$ samples

FT-IR spectroscopy of CO$_2$ molecule absorbed on different reduced samples at 800°C

Switching on electrocatalytic activity in solid oxide cells

J.H. Myung, D. Neagu, D.N. Miller & J.T.S. Irvine

Nature, 2016. 537, 528-531
CO\textsubscript{2} Electrolysis at LCNT, 900\textdegree C

CO$_2$ Electrolysis at La$_{0.43}$Ca$_{0.37}$Ni$_{0.06}$Ti$_{0.94}$O$_3$
Overview

- Direct CO\(_2\) electrolysis can be facilitated by surface control and manipulation especially at emerged nanoparticles
- Enhancement shown for
  - Ni emergence from A site deficient perovskite
  - Manganese surface
    - Vacancy Mn couple thought important
  - Ceria nanoparticle
- Electrochemical switching can be applied
Carbon Dioxide electrolysis to syngas: enabling through electrochemical switching at nanoscale via oxide or protonic conduction to macroscale concept.
Speaker Introductions

Professor John Irvine  
Professor of Chemistry  
St Andrew’s University

Sam French  
Business Development  
Johnson Matthey

Jane Patterson  
Technology Strategy  
Ricardo Strategic Consulting

Samuel Perez Ramirez  
Hydrogen & Heat Leader  
Scottish Power Renewables
Sam French
Senior Business Development Manager
Johnson Matthey
Scaling up CCM production for PEM electrolysis

Sam French

February 2021
We focus on sustainable technology

Shaping a new era of clean energy from low carbon energy sources

Achieving more from less through process efficiency design and recycling

Providing clean air for all with emission control and zero emission technology

Helping people live longer, healthier lives by drug development and manufacture

UN SDGs

7 Affordable and clean energy

12 Responsible consumption and production

11 Sustainable cities and communities

3 Good health and wellbeing
We work in collaboration

Long term relationships

Risk sharing

Understanding our customers’ needs

Collaboration
Investing in Green Hydrogen

- Established new Green Hydrogen business unit, seeing significant growth potential as countries, regions, and companies set ambitious targets
- JM technologies already at the heart of enabling clean hydrogen production and fuel cell applications
- JM is increasing efforts on green hydrogen, leveraging core science capabilities and market expertise to drive large scale adoption
- Scaling up R&D and manufacturing, leveraging state-of-the-art site in Swindon, UK
Technology enabling the PEM electrolyser value chain

**Upstream**
- PGM supply & refining
- Catalyst-coated membranes

**Hydrogen production**
- Electrolyser system
- Hydrogen production

**End uses**
- Power-To-X Projects
- End-of-life

**Recycling**
- Recycling

---

*PGM chemistry and electrocatalysts to do more with less*

*Scale-up of fuel cell and electrolyser key components*

*Electrolyser-based Power-to-Hydrogen systems and services*

*Electrolyser-integrating energy system design*

*Market-leading technology in petrochemical applications*

*World’s largest secondary pgm refiner – design-for-recycle*
JM expertise in PGM for electrolysers

**PGM Expertise**
Product offering is not just about the materials we can provide – also about expertise and experience within this space that will help add value.

**JMM expertise**

- Pt Black HSA
- Pt / C
- Ir Black
- IrOx
- Pt DNS
- Plating expertise
- Refining
- Metal management and procurement
CCMs for PEM Electrolysers – What our technical focus is today

Synergy to fuel cells

**Anode layer**
- Thrifting of the catalyst
- Balance activity/stability

**Membrane**
- Thickness vs. H₂ crossover
- Additives

**Membrane/Cathode layer**
- Low H₂O₂ formation catalysts

![Diagram of PEM electrolyzer components](image)

- Proton exchange membrane (PEM)
- Gas diffusion layer
- Porous transport layer
- Water
- Oxygen
- Anode catalyst
- Cathode catalyst
- Electric current
- Hydrogen
- Wet cell testing
- Current density → Voltage
- Membrane/Cathode layer → Voltage → Current density
- Ref
- Thin membrane
- Thin membrane + crossover mitigation
- Time → H₂ crossover
- Novel project

© 2020 Johnson Matthey PLC
Experience to lean on: manufacturing excellence of fuel cells

Roll to roll fabrication
- Reduction in manufacturing cost
- Class 1000 cleanroom

Component manufacture
- Flexible design of catalyst layer coatings
- Membrane manufacture
- Automated conversion

Beyond 3 component
- Edge seal and sub-gasket incorporation in CCM
- In-line vision system for dimensional alignment

Quality assurance
- In line monitoring at speed
- Achieve high product specification
- Product traceability

© 2020 Johnson Matthey PLC
JM is well positioned for the electrolyser market

Science
- Catalyst and membrane expertise
- Optimisation for high performance

Pgm expertise
- Potential closed loop offering
- Ability to reduce cost

Trusted partner in fuel cells
- Proven commercial product
- Existing customers
- Over 20 years’ experience

Experienced in CCM manufacturing
- Reduction in manufacturing cost
- Efficient processes
- Leverage knowledge for electrolyser CCMs

© 2020 Johnson Matthey PLC
Jane Patterson
Technology Strategy Consultant
Ricardo Strategic Consulting
Adopting a Life Cycle Philosophy

Session 2 – Green Hydrogen and Ammonia Production

Thursday 25 February

Jane Patterson, Ricardo UK
What is Life Cycle Assessment?

- Life Cycle Assessment (LCA) is about taking a holistic approach to the analysis of a product’s environmental impact
- All things have a life cycle of “birth”, “use/service” and “death” in which they impact on their environment
- **Life Cycle Assessment (LCA)** is a technique for quantifying the environmental and human health impacts of a product over its life cycle
  - Other names include “life cycle analysis”, “life cycle approach”, “cradle-to-grave analysis”, “ecobalance” or “environmental footprinting”
  - The process for conducting LCA is outlined in ISO 14040:2006 and ISO 14044:2006
- **Life Cycle Philosophy** is a way of thinking that includes the economic, environmental and social consequences of a product or process over its entire life cycle

**Formal Definition of Life Cycle Assessment**

“It is a process to evaluate the environmental burdens associated with a product, process or activity by identifying and quantifying energy and materials used and wastes released to the environment. The assessment includes the entire life cycle of product, process or activity, encompassing extracting and processing raw materials, manufacturing, transport and distribution; use, re-use, maintenance; recycling, and final disposal”

SETAC, 1991
What is included in the Vehicle Life Cycle?

Vehicle Production
Assessment of environmental impact of producing the vehicle including extract of raw materials, processing, component manufacture, logistics, vehicle assembly and painting

Fuel Production
Assessment of environmental impact of producing the energy vector(s) from primary energy source to point of distribution (e.g. refuelling station)

Use
- Environmental impact of driving
- Impact from maintenance and servicing

End-of-Life
Assessment of environmental impact of “end of life” scenario, including re-using components, recycling materials, energy recovery, and disposal to landfill

Analysis of the whole vehicle life cycle will include embedded emissions from vehicle production, maintenance and servicing, and end-of-life activities, and WTW emissions from production and use of the fuel / energy.

Well-to-Wheel (WTW) Analysis is Life Cycle Assessment of the fuel (energy) used to power the vehicle.

“Embedded” emissions result from vehicle production; fluid, filter and component replacement during life; and end-of-life activities. A “cradle-to-gate” LCA study may only consider vehicle or component production.
Why do we need to take a life cycle approach?

Estimation of GHG emissions for European Medium Passenger Car (2020)

<table>
<thead>
<tr>
<th></th>
<th>Tailpipe</th>
<th>Well-to-Wheels</th>
<th>Vehicle Life Cycle</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gasoline ICEV</td>
<td>38.9</td>
<td>51.6</td>
<td>59.9</td>
</tr>
<tr>
<td>Gasoline FCEV</td>
<td>0.0</td>
<td>13.1</td>
<td>24.9</td>
</tr>
<tr>
<td>BEV</td>
<td>0.0</td>
<td>24.5</td>
<td>35.6</td>
</tr>
<tr>
<td>ICEV</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fuel / Electricity Production (EU-28 Base Blend)</td>
<td>0.0</td>
<td>11.1</td>
<td>24.9</td>
</tr>
<tr>
<td>Vehicle Maintenance</td>
<td>11.1</td>
<td>13.1</td>
<td>35.6</td>
</tr>
<tr>
<td>Total</td>
<td>0.0</td>
<td>24.5</td>
<td>35.6</td>
</tr>
</tbody>
</table>

Life Cycle Assessment provides us with deeper understanding of the environmental impacts of our technology decisions.

To truly achieve net zero mobility, we need to reduce emissions from across the vehicle value chain, not just point-of-use.

Why do ZEVs have higher embedded emissions?

Vehicle Production GHG emissions for European Medium Passenger Car (2020)

Vehicle OEMs such as VW have published their glide path to net zero BEVs. What is the net zero glide path for fuel cell vehicles?

What design, material and manufacturing changes can we make to reduce the embedded emissions from on-board hydrogen storage, while still ensuring the storage solution meets its system requirements?

How can we re-use / recycle the on-board hydrogen storage system at end-of-life?

Source: Ricardo Vehicle LCA analysis for average 2020 EU lower-medium passenger car (C-segment) (November 2020). Analysis assumed BEV has 50 kWh Li-ion battery pack, and FCEV has 96 kW PEM FC, 2.3 kWh Li-ion battery and 3.8 kg H2 on-board storage.
Which study should I read to know more?

- Ricardo, in collaboration with ifeu and E4Tech, has recently completed a major policy LCA study for the European Commission DG CLIMA.
- The study compared the life cycle environmental impacts of light and heavy duty vehicles covering a selection of major powertrain types and fuel chains for 2020 to 2050 timeframe:
  - 65 different vehicle and powertrain technologies
  - EU + 28 countries
  - 70+ fuel & electricity chains
  - 14 environmental impact categories
- The policy-oriented LCA methodology, based on an extensive literature review and stakeholder consultation, enables like-for-like comparison across powertrain types.
- A (very) small subset of results from this study have been shared today.

Samuel Perez Ramirez

Hydrogen & Heat Leader
Scottish Power Renewables
Green H₂ vision, projects and needs

H2FC Research Challenges and Opportunities – An Industrial Perspective

Samuel Perez
Thursday 25 Feb 2021
The evolution of technology will be driven by the **decarbonization challenge**…

... resulting in more **renewables**, more **networks** & efficient **storage**, more **smart solutions** and **Green Hydrogen**
Context: H₂ today – Industrial Feedstock

Current Opportunity:
- NG + Oil 75%
- Coal 24%
- Electricity <1%

Processes:
- SMR
- Gasification
- Electrolysis

H₂ Production:
- 80 Mt
- EUR 1-2 /Kg
- 830 Mt CO₂

Electrifiable Industrial H₂ production:
- 3.000 TWh/yr
A new energy context

**Green Hydrogen**, key to decarbonize **industrial uses** and hard-to-abate sectors

*Current EU final energy demand*

- Electrifiable with available clean technologies

![Energy Demand Diagram](image)

- Need for **Green Hydrogen**: the remaining 16% will be crucial for the decarbonisation

**Current Opportunities**

- From grey to Green Hydrogen in current uses
- **On site Generation**
  - Industrial feedstock
  - Chemicals

**Future Opportunities**

- **Hard-to-abate sectors**
  - Maritime transport
  - Air transport
  - High temp Industry

**Additional Challenges**: Transportation, distribution and use.

Source: Elaborated from data corresponding to Europe energy demand (EUROSTAT)
Cost reductions achievable

**Key drivers for green H\textsubscript{2} production cost reduction**

- **Electricity cost**: ~ 30-40% Solar PV, onshore & offshore wind
- **Electrolyzer Capex**: ~ 40-50% Economies of scale, innovations
- **Electrolyzer Load Factor**: ~ 10-20% Higher load factors from renewables

**Cost range of Green H\textsubscript{2} Production, €/kg**

The price of electricity is the dominant component cost, well above CAPEX
H₂ properties lead to high transport & storage cost

Density of hydrogen in different states

Volumetric energy density of hydrogen and methane

Energy required for hydrogen compression

Energy requirement for hydrogen liquefaction
There are very difficult uses to electrify (with current technology!)

16% of the final energy demand is **hardly electrifiable** ...

H₂ (and other renewable gases) may play a role in their decarbonization

<table>
<thead>
<tr>
<th>Difficult to electrify uses</th>
<th>% of final energy demand in the EU</th>
<th>% of CO₂ emissions in the EU</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shipping</td>
<td>0,5%</td>
<td>4%</td>
</tr>
<tr>
<td>Aviation</td>
<td>0,6%</td>
<td>4%</td>
</tr>
<tr>
<td>Heavy road transport</td>
<td>8%</td>
<td>6%</td>
</tr>
<tr>
<td>High-temperature industry*</td>
<td>7%</td>
<td>4%</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>16%</strong></td>
<td><strong>18%</strong></td>
</tr>
</tbody>
</table>

* High-temperature industry (>500 °C): iron and steel production, cement, chemical industry.
Our Plans

• Pipeline
• Industrial value chain

Puertollano 20MW Green Hydrogen plant
Global H₂ business unit to serve a global rising demand

Iberdrola is commissioning the largest project in EU by 2021 and an ambitious plan to 2025 and beyond.

Iberdrola green hydrogen business has gone global, with developments in regions where Iberdrola operates.

**Priorities in the short term:**

**Operating Plan: The Fertiberia case**

- **Target:** make FB’s ammonia production green in this decade
- **Investments** 1800 M€
- **Electrolyzer to be installed:** 800 MW
- **Associated PV** : 1400 MW

Additionally, Iberdrola has full commitment with the development of the value chain to meet the ambitious targets:

Born to become the **industrial champion for electrolyzers manufacturing at Spain**

**Electrolyzer Capacity (MW)**

<table>
<thead>
<tr>
<th>Year</th>
<th>Capacity (MW)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2021</td>
<td>20</td>
</tr>
<tr>
<td>2023</td>
<td>280</td>
</tr>
<tr>
<td>2025</td>
<td>800</td>
</tr>
<tr>
<td>2030</td>
<td>9,000</td>
</tr>
</tbody>
</table>

**H₂ Production (Ton/yr)**

<table>
<thead>
<tr>
<th>Year</th>
<th>Production (Ton/yr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2021</td>
<td>1,000</td>
</tr>
<tr>
<td>2023</td>
<td>2,500</td>
</tr>
<tr>
<td>2025</td>
<td>15,000</td>
</tr>
<tr>
<td>2030</td>
<td>85,000</td>
</tr>
</tbody>
</table>

On site replacement of existing grey H₂ uses:

- Fertilizers industry
- Petrochemical sector
- Glass producers
- Hydrogenated fats sector
**IberLyzer: How? – Details**

IberLyzer’s mission is to provide turnkey large scale electrolyzer systems to customers with high hydrogen demand leveraging a multiple value proposition:

- Iberdrola and Ingeteam have created IberLyzer, a company dedicated to the integration, installation and maintenance of electrolyser plants.
- Ingeteam is an international technological group with presence in more than 24 countries, specialized in power and control electronics, and electric machines, systems and services to enhance renewable integration and power grids.
- IberLyzer will begin operations next year and will integrate over 200 MW of electrolysers by 2023, investing up to EUR 100 M and creating 150 direct jobs.

IberLyzer is born to fulfill a market need the same way...
What is needed to achieve this target? An open debate

• **REN** are responsible for the 70% of cost, we hope they will reduce cost as expected

• **EZ CAPEX is responsible** for 30% of produced H₂. Iberlyzer will be directly involved in this goal. We’re interested in (among others):
  • Stack increased **performance**
  • **Automated** manufacturing systems
  • New cheaper and available materials (structural, catalyst, etc.)
  • Easy maintenance designs
  • Modular integration of BOS and BOP

• **Transport and storage** are important contributors to LCOH. **Ammonia** could be a solution also as a energy vector
  • **Modular** (smaller) **Ammonia production facilities**, not dependent on steam
  • Improvement in **direct uses of ammonia**. Shipping engines, use in GT….
  • Suitable regulation for **handling and managing Ammonia** in new uses
  • Cost sensible **Ammonia splitting facilities**
  • Use of hydrogen in steelmakers still needs improvement and cost reductions
The target is the decarbonization of H$_2$ feed stock industrial uses and of traditional **hard-to-abate sectors** (high temperature industry, shipping and aviation).

Renewable cost reductions, capacity factors increase, and hydrogen **technology costs reductions** (thanks to industrial projects pipeline) are key to reach those objectives.

Full commitment with the development of the value chain to meet the ambitious targets. **IberLyzer** is the first step and there will be more to come. Ammonia could be the hidden player.
Thank You
Breakout group discussion - Green Hydrogen and Ammonia Production

- Chair will assign someone to take NOTES - they can share the screen with others if useful.
- 45 minutes discussion, then we’ll return to the main room to wrap up.
- Use the CHAT function to capture more views

Group discussion guide

- Explore
  - What are the specific technological challenges in your product/service or research?
  - What would an ideal world look like? Which technologies do you think will be there in 10 years, 20 years?
  - What are the opportunities? What are the risks?

- Reflect
  - What could be done to improve the situation?
  - How can Industry and Academia collaborate better?
  - How can H2 demonstration projects feed back to academia and how can academia help to solve issues?
  - How could a National Hydrogen Programme help to develop this field further?
Discussion topic…

Key observations from the discussion:

(notes)

Proposed next steps for Industry-Academia collaboration:

Very important! Please send notes at the end of the discussion to

h2fc@imperial.ac.uk
Thank you

• We will be putting together a report from this workshop which will be available on the H2FC website in due course.

• We’re updating our capability document – please respond to the email about this so we can ensure we have your up-to-date details!

• Become a member of the H2FC Supergen Hub and subscribe to our newsletters

• Please send any feedback to h2fc@imperial.ac.uk