The journey so far…

Hydrogen Research Coordinators

Two linked coordinator projects:

Research Challenges in Hydrogen and Alternative Liquid Fuels

Tackle research challenges that underpin production, storage, distribution and end-use, including:

- Lowering costs
- Increasing efficiencies
- Materials science and engineering
- Hydrogen safety

UK-HyRES

Principal Investigator
Prof Tim Mays
University of Bath

Co-Investigator
Prof Rachael Rothman
University of Sheffield

Co-Investigator
Prof Shanwen Tao
University of Warwick

Systems Integration of Hydrogen and Alternative Liquid Fuels

- Integration within the whole energy system that includes:
- Whole systems integration across technologies
- Trade-off analysis across technology options
- Technology coupling requirements
- Whole systems

HI-ACT
Hydrogen Integration for Accelerated Energy Transitions

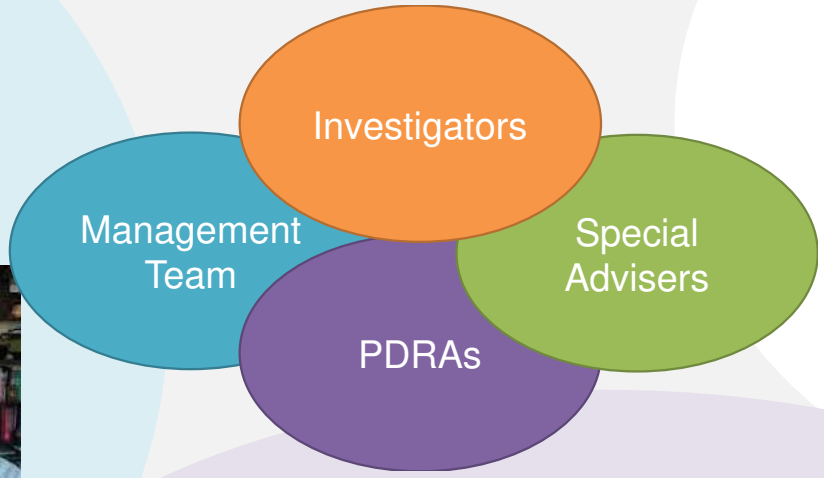
PI: Prof Sara Walker
Newcastle University

Project Manager
Dr Yankı Keleş
University of Bath

Project Support
Amanda Lester
University of Bath

Project Support
Carla Teale
University of Sheffield

Project Support
Matt Phillips
University of Warwick



SCOTTISH Hydrogen & Fuel Cell ASSOCIATION

ITM POWER
Energy Storage | Clean Fuel

SIEMENS energy

WALES&WEST UTILITIES

HSE
Health & Safety Executive

JAGUAR

LAND ROVER

GKN AEROSPACE

Research Support
Dr Rajan Jagpal
University of Bath

Research Support
Dr Diarmid Roberts
University of Sheffield

Research Support
Dr Mengfei Zhang
University of Warwick

Facilitation and Visualisation

THE COLLECTIVE

Scriberia

Hydrogen Research Coordinator:
Research Challenges in Hydrogen & Alternative Liquid Fuels

UK-HyRES

https://ukhyres.co.uk

@UkHyres

VISION An **inclusive**, **inter-disciplinary** community to **co-create** a plan to tackle the research challenges in hydrogen & alternative liquid fuels for Net Zero. This will lay the foundation of a **UK Centre of Research Excellence in Hydrogen & Alternative Liquid Fuels**

Identification & prioritisation of research challenges ⟷ A uniquely connected & informed H&ALF research community

Theory of Change Implemented through accessible, facilitated workshops with direction from special advisers

Why?	What?	How?	How?	What?	Why?
Strategic Drivers	Challenges & Barriers	Opportunities for Research	Outputs	Change (Outcomes)	Impact (Difference & Added Value)

May:

ONLINE LAUNCH

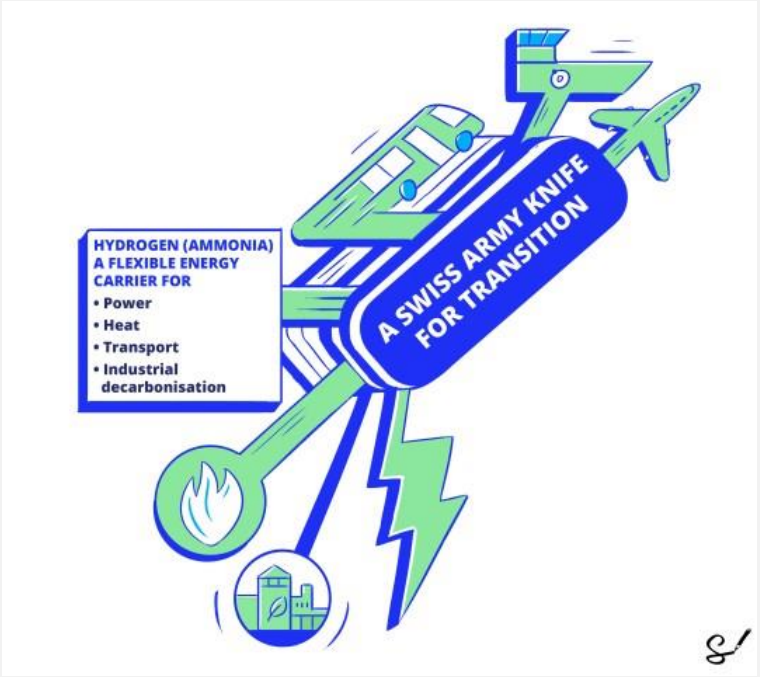
Prof Paul Monks
CSA, BEIS

June and July:

ONLINE WORKSHOP 1 – Hydrogen production
ONLINE WORKSHOP 2 – Hydrogen storage / distribution
ONLINE WORKSHOP 3 – Hydrogen end use
ONLINE WORKSHOP 4 – Alternative carriers

Autumn:

~~IN PERSON SHOWCASE – Reflections and plans~~
ONLINE 21st October



Extension

- Phase 2 co-ordination from 1 October 2022 to 31 April 2023
- Continue 1-2-1 interviews with thought leaders in H&ALFs
- Strong engagement with Systems Co-ordinator
- Further analysis / synthesis of all engagement outcomes
- Re-arrange in-person Showcase to 21 October 2022
- Respond to Hub call by 2 November 2022
- Continue to develop projects that will sit in Hub

Derek Craig
UKRI Director of Cross Cutting Council Programmes

Vision for the Hub

Hub Call

UK Research and Innovation

Funding opportunity

EPSRC hydrogen programme to establish hydrogen research hubs

Opportunity status:	Open
Funders:	Engineering and Physical Sciences Research Council (EPSRC)
Funding type:	Grant
Total fund:	£25,000,000
Maximum award:	£12,500,000
Publication date:	1 September 2022
Opening date:	1 September 2022
Closing date:	2 November 2022 16:00 UK

Timeline

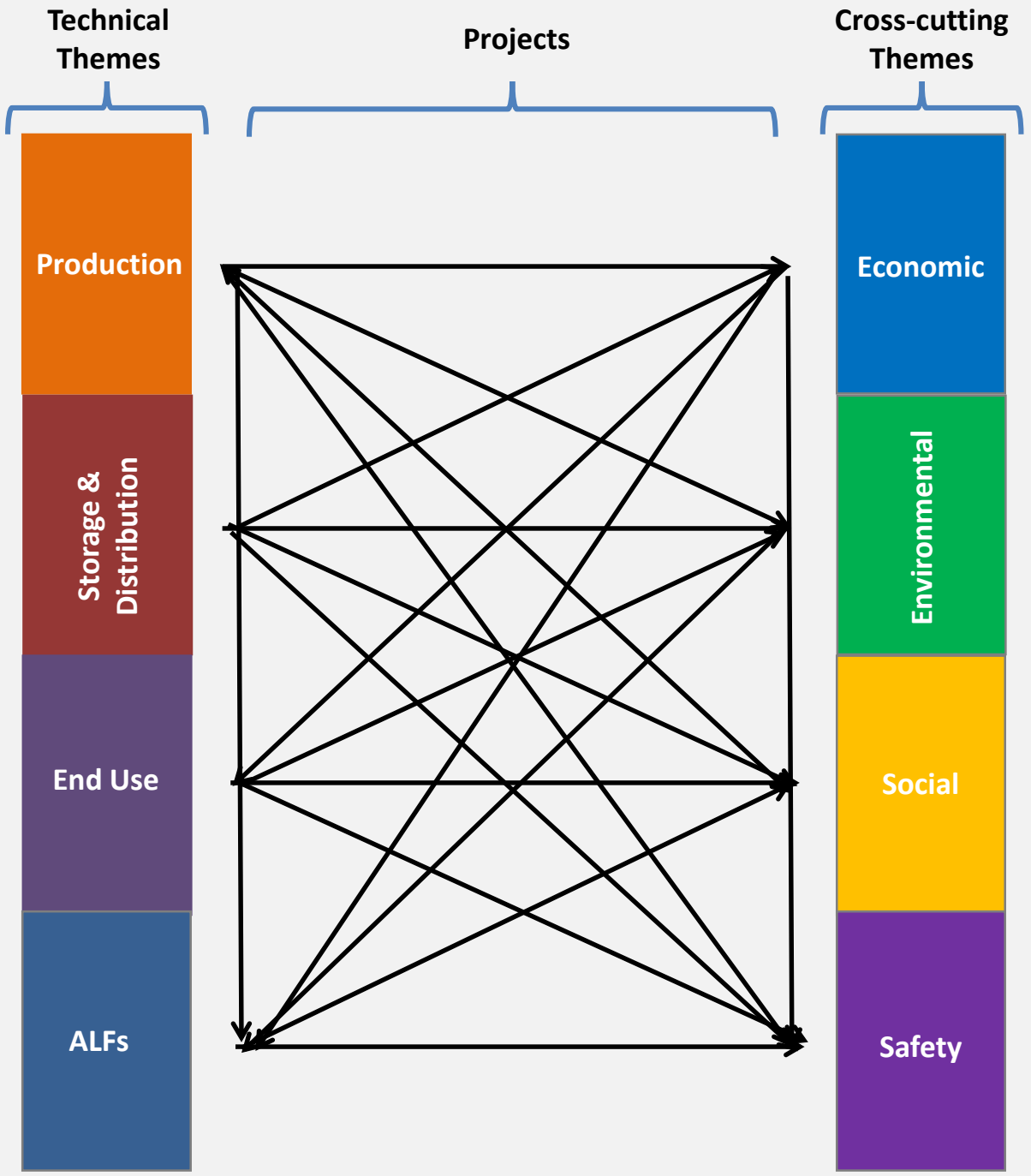
- **1 September 2022 00:00**
  Opening date
- **2 November 2022 16:00**
  Closing date
- **1 April 2023**
  Earliest start date

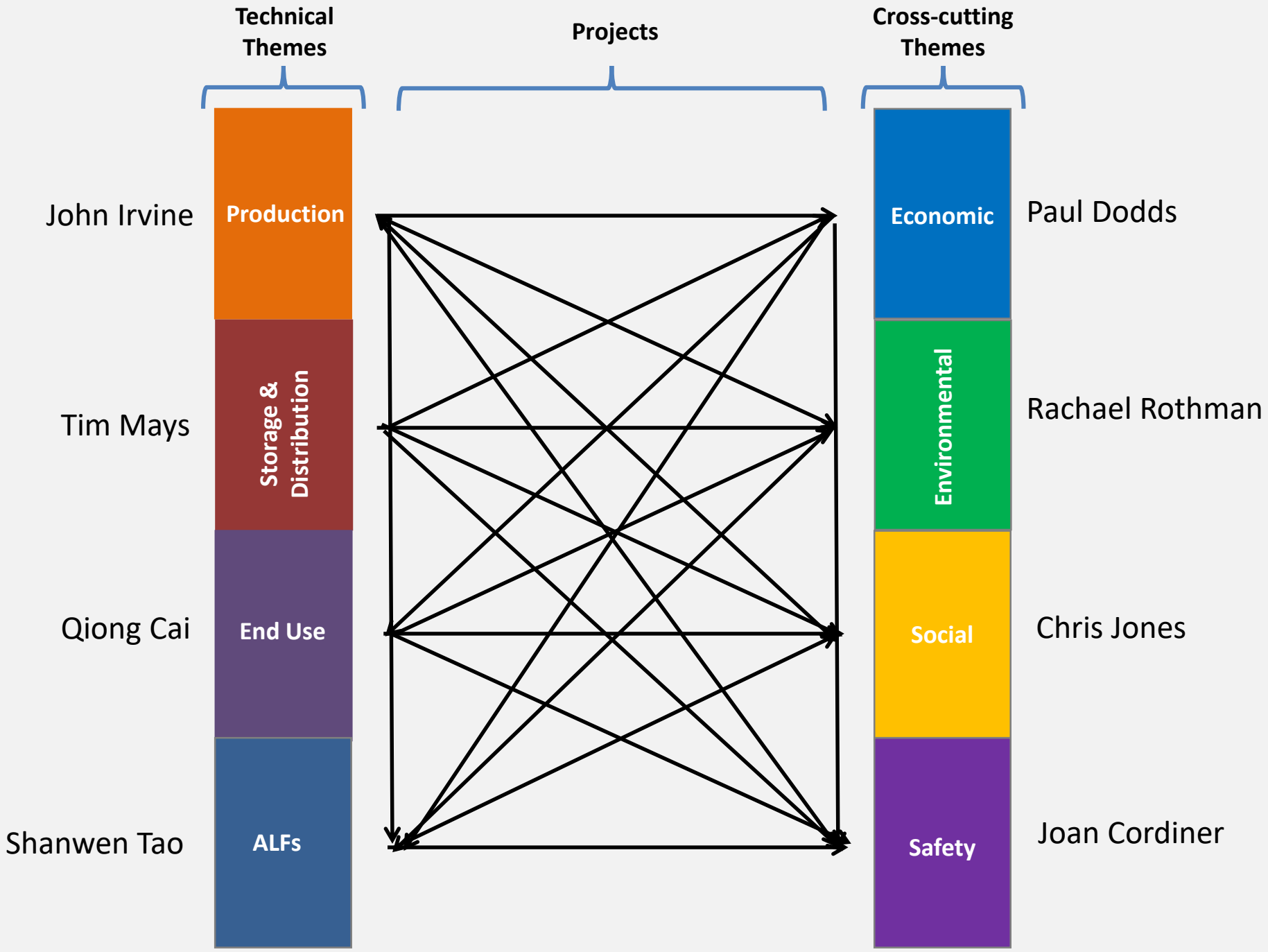
Guidance on good research

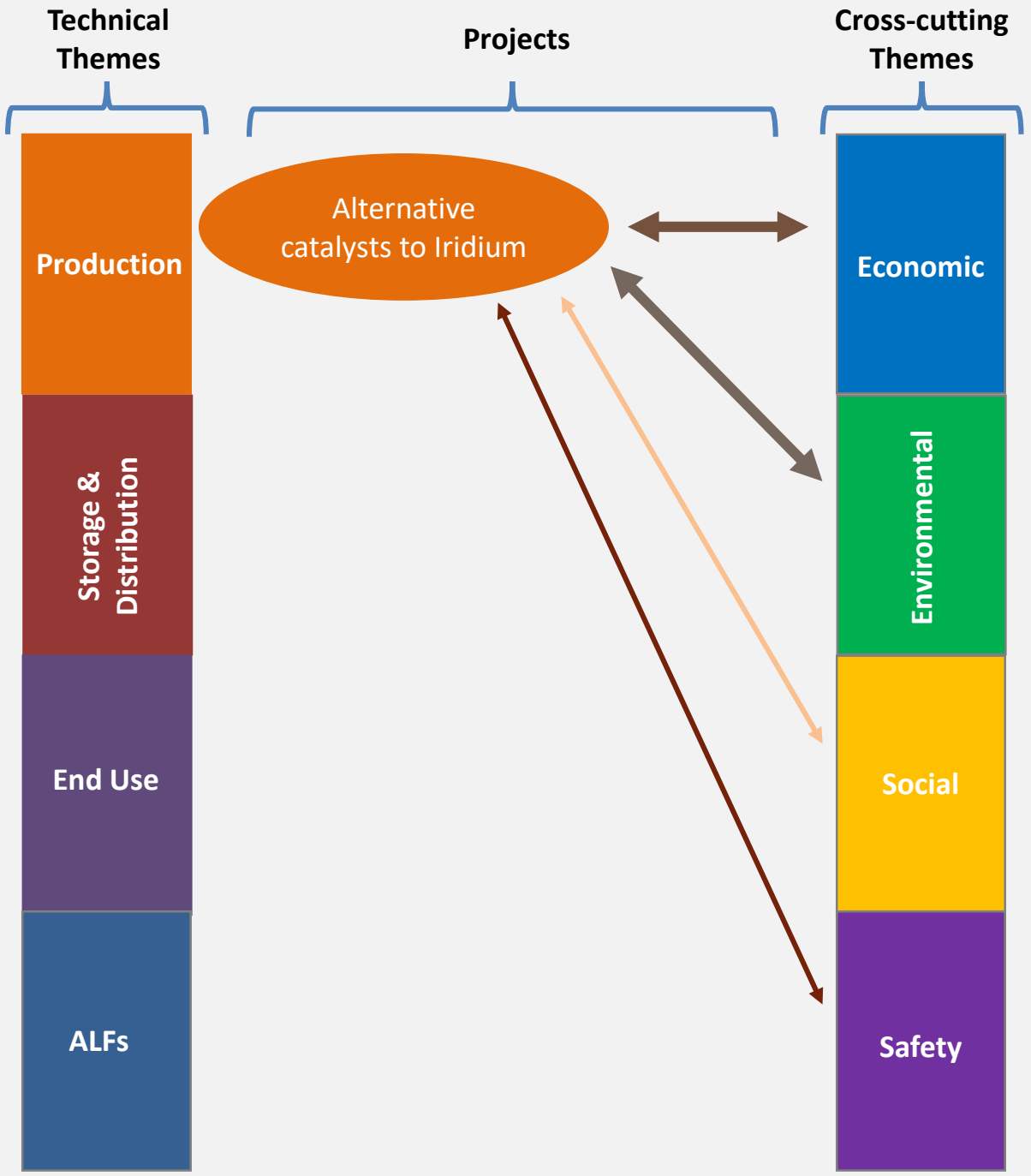
Hub Summary

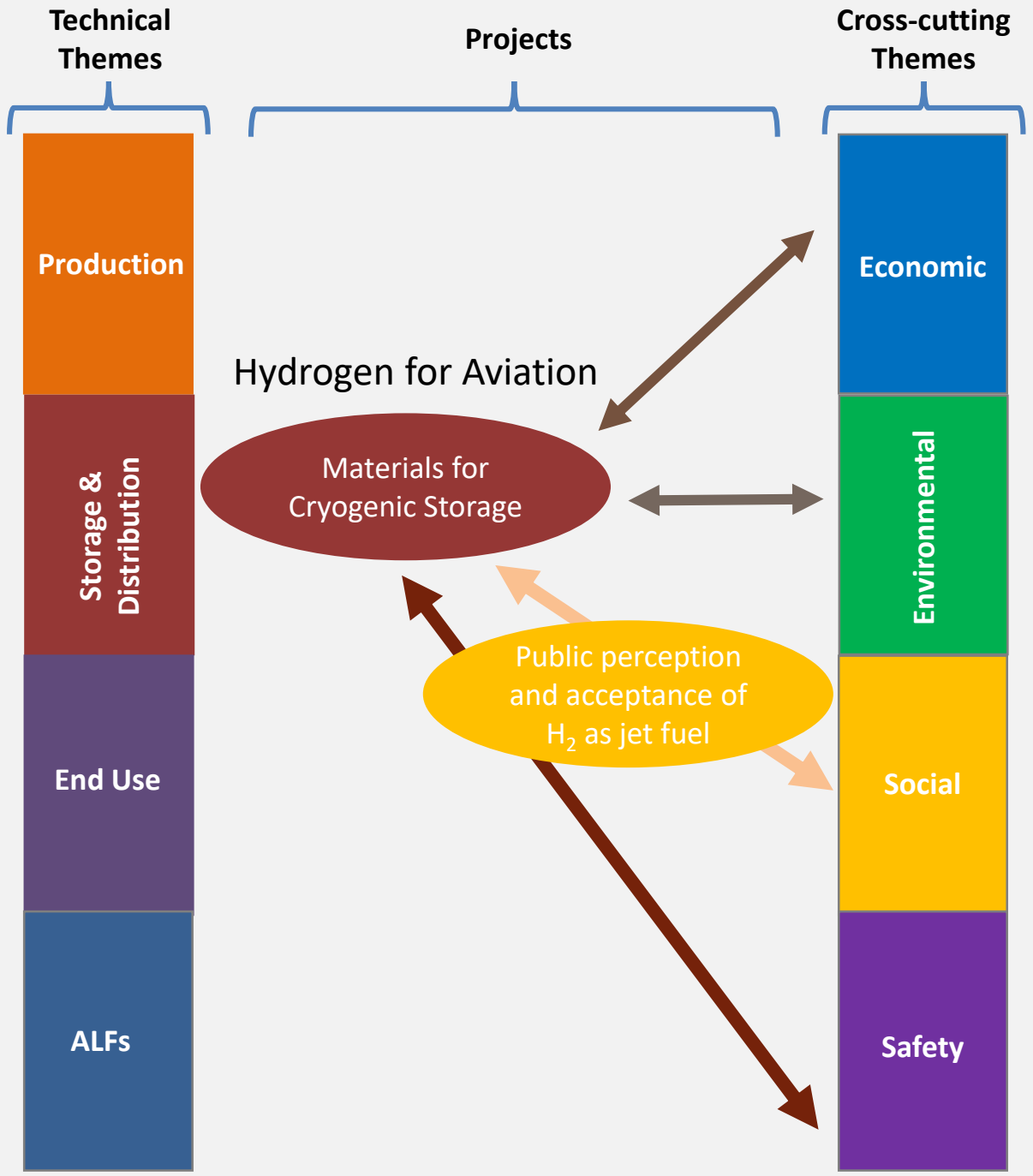
- Five years from 1 April 2023 (at earliest) with review points
- £12.5M Full Economic Cost / £10.0M EPSRC (@ 80 % FEC)
- At least £3.0 M leveraged funding by Hub start
- At least a further £7.0M leveraged funding during Hub
- Costs: Hub Operations + Themes + Projects
  - £425k FEC per 3 y project for up to 10-15 projects initially
- Four TECHNICAL Themes: Production, Storage, End Use , ALFs
- Four CROSS-CUTTING Themes: Economic, Environmental, Social, Safety

HUB STRUCTURE




Technical Themes
Projects
Cross-cutting Themes
John Irvine
Production
Tim Mays
Storage & Distribution
Qiong Cai
End Use
Shanwen Tao
ALFs
Economic
Paul Dodds
Environmental
Rachael Rothman
Social
Chris Jones
Safety
Joan Cordiner

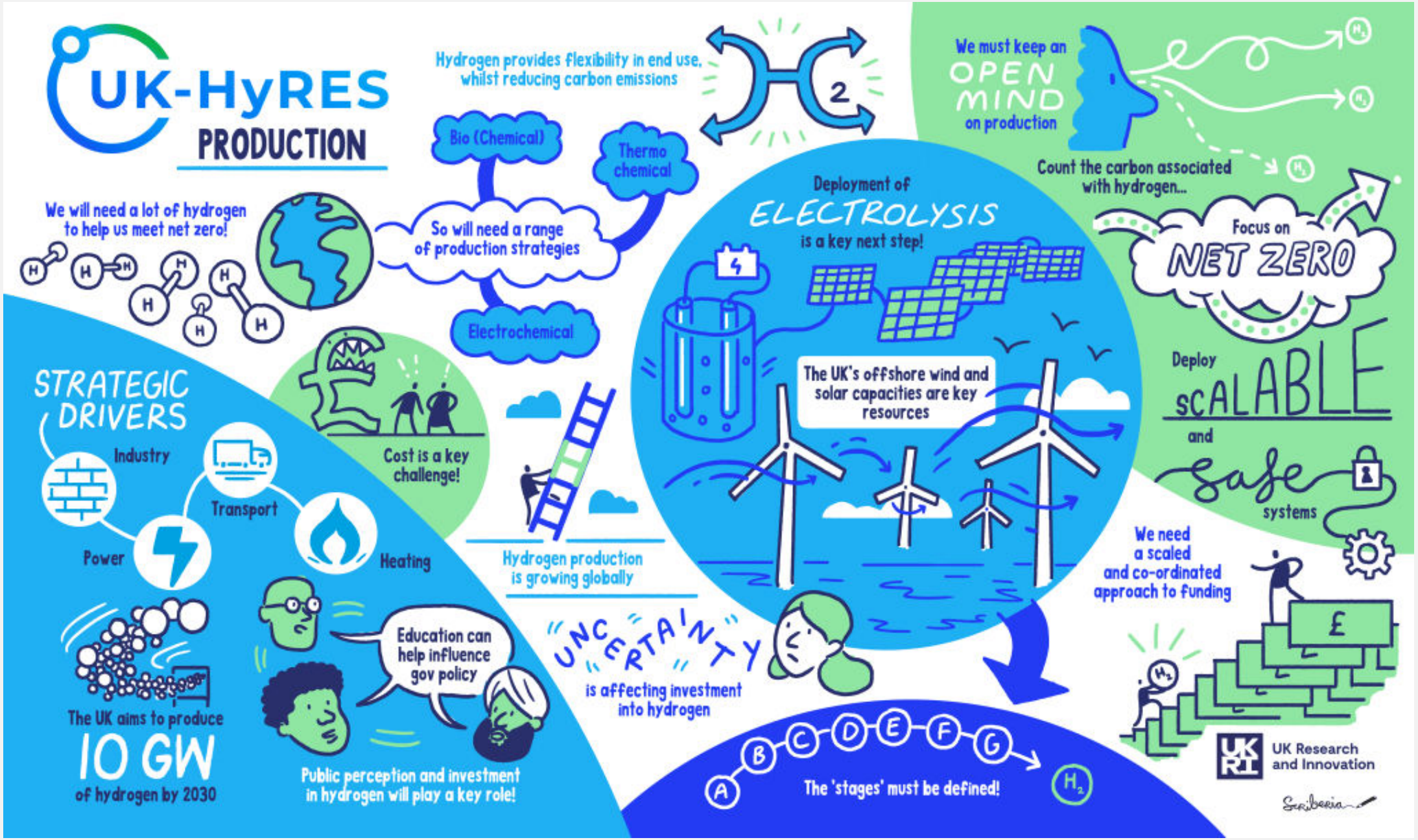

Technical Themes
Projects
Cross-cutting Themes
Production
Storage & Distribution
End Use
ALFs
Alternative catalysts to Iridium
Economic
Environmental
Social
Safety


Technical Themes
Projects
Cross-cutting Themes
Production
Storage & Distribution
End Use
ALFs
Hydrogen for Aviation
Materials for Cryogenic Storage
Public perception and acceptance of H_2 as jet fuel
Economic
Environmental
Social
Safety

Our Job Today…

What projects should we be doing that will make the biggest step change and why?

Hydrogen Production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PRODUCTION
Hydrogen provides flexibility in end use, whilst reducing carbon emissions
Bio (Chemical)
Thermo chemical
Electrochemical
So will need a range of production strategies
We will need a lot of hydrogen to help us meet net zero!
We must keep an OPEN MIND on production
Count the carbon associated with hydrogen...
Deployment of ELECTROLYSIS is a key next step!
The UK's offshore wind and solar capacities are key resources
Focus on NET ZERO
Deploy SCALABLE and safe systems
STRATEGIC DRIVERS
Industry
Transport
Power
Heating
Cost is a key challenge!
Hydrogen production is growing globally
UNCERTAINTY
is affecting investment into hydrogen
Education can help influence gov policy
Public perception and investment in hydrogen will play a key role!
The UK aims to produce 10 GW of hydrogen by 2030
We need a scaled and co-ordinated approach to funding
A B C D E F G
The 'stages' must be defined!
UK Research and Innovation

Production

Challenges	Potential project areas
1. Alternative catalysts to Iridium	Alternative oxygen evolution reaction catalysts to Iridium.
2. Anionic exchange membranes	Develop step-change anionic exchange membrane.
3. Solid oxide electrolyser development	Oxygen electrode spalling, hydrogen electrode Ni migration, improving durability and reducing manufacture cost of solid oxide electrolyser technology.
4. Seawater electrolysis research	Fundamental research on seawater electrolysis.
5. Bio-based routes	Bio-based routes to hydrogen production.
6. Solar and Nuclear hydrogen production	Using solar or nuclear energy as the energy source for hydrogen production.

Hydrogen Storage & Distribution

UK-HyRES
STORAGE & DISTRIBUTION

This is a chance for you to help shape the national agenda

Public acceptance of hydrogen and storage is a key challenge

There is a knowledge gap in how liquid storage can work

Safety is paramount in storage solutions!

UPSKILLING WILL HELP!!

Hydrogen is not an energy source, it is a VECTOR

it can be stored at SCALE and at reasonable cost

COST is a key factor

We need a range of storage options for hydrogen

H_2

CARBON FIBRE TANKS

SOLID STATE

CHEMICAL STORAGE

SALT CAVERN STORAGE

LIQUID HYDROGEN

Capacity will be limited for

100% H_2

We need SYSTEM TARGETS not material targets!

The store must be effectively integrated with hydrogen and the application

R&D must focus on SHORT & LONG term targets!

Co-creation and collaboration will be essential

BLENDING can play a big role. The natural gas grid can be utilised

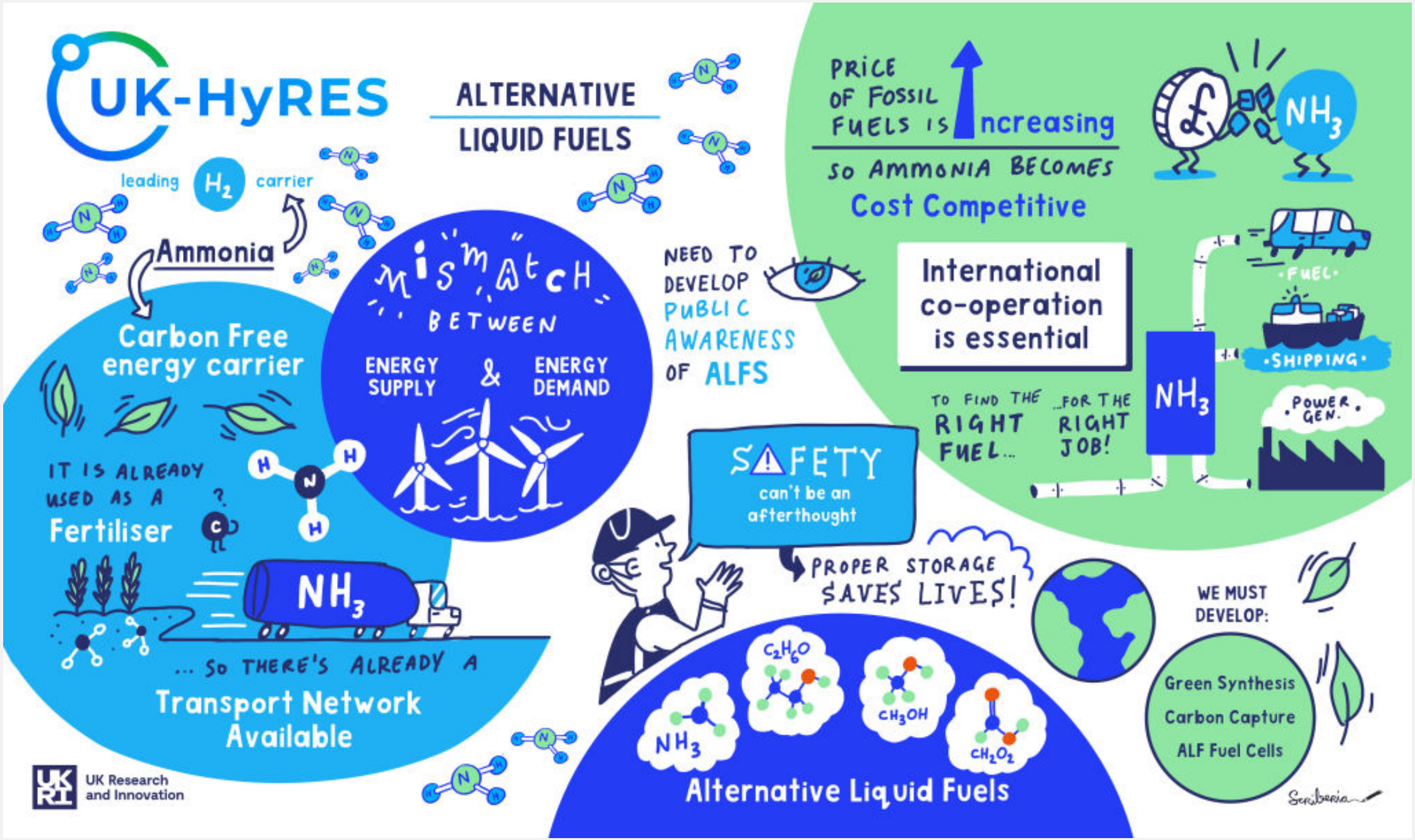
UK Research and Innovation

Sciberia

Storage & Distribution

Challenges	Potential project areas
7. Cryogenic material behavior	Material behavior under cryogenic/ambient cycling. Including material embrittlement models and experiments.
8. Permeation barrier development	Develop novel non-metallic barriers to permeation.
9. Thermal energy recovery	Thermal energy recovery from compression and liquefaction and improvement of compressor technology.
10. Solid state storage	New solid state materials and scale-up of existing solid state storage.
Cross-cutting	
11. H_2 sensor development	Development of novel H_2 sensors, e.g. low-cost, in-line, real time & cryo-compatible.
12. Storage vessel leakage and failure	Modelling leakage and failure mechanics of storage vessels, including O_2/N_2 condensation.

Alternative Liquid Fuels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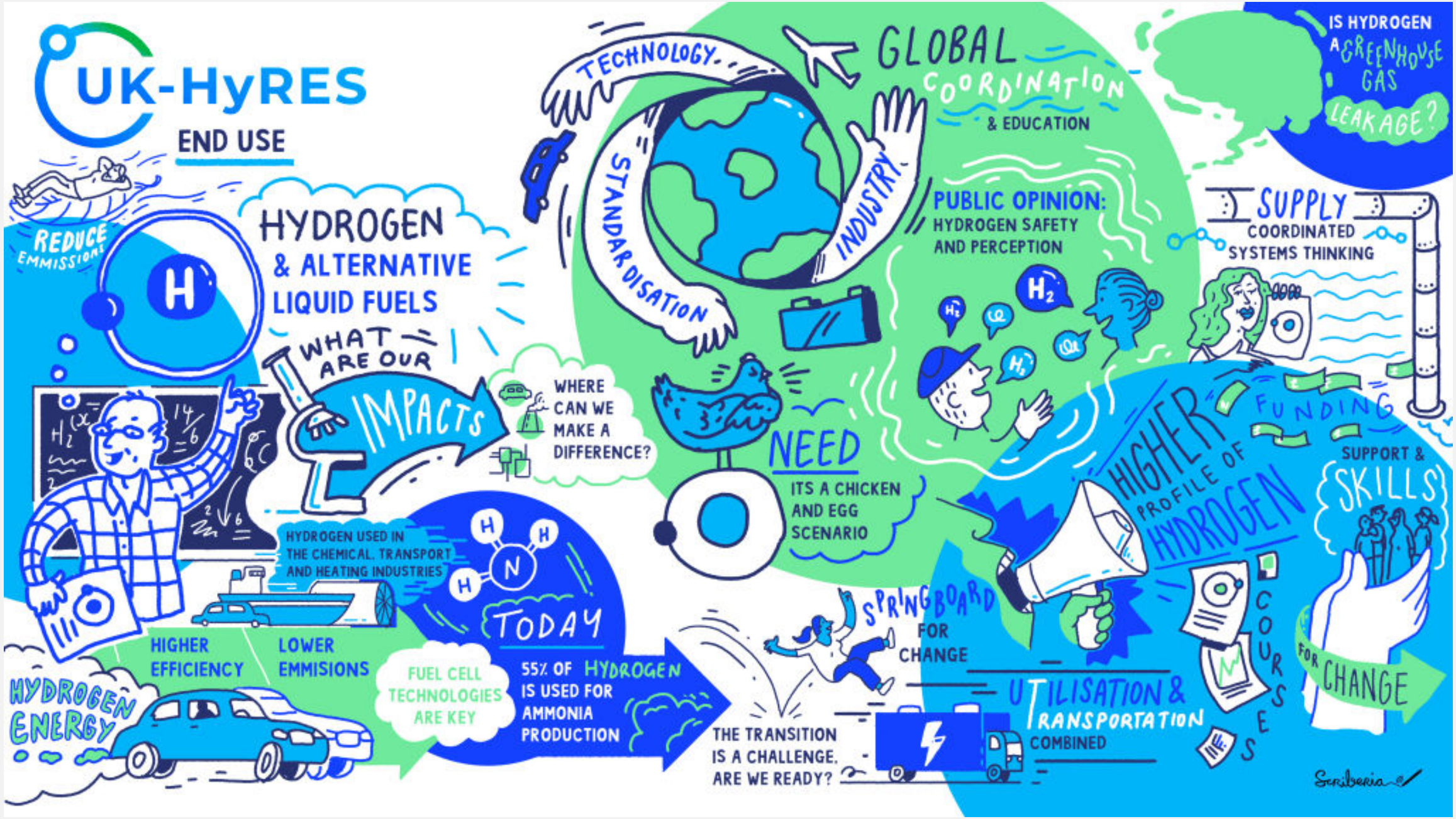
ALTERNATIVE LIQUID FUELS
leading H_2 carrier
Ammonia
Carbon Free energy carrier
IT IS ALREADY USED AS A Fertiliser
NH_3
... SO THERE'S ALREADY A Transport Network Available
MISMATCH BETWEEN ENERGY SUPPLY & ENERGY DEMAND
NEED TO DEVELOP PUBLIC AWARENESS OF ALFS
PRICE OF FOSSIL FUELS IS Increasing
SO AMMONIA BECOMES Cost Competitive
International co-operation is essential
TO FIND THE RIGHT FUEL...
...FOR THE RIGHT JOB!
FUEL
SHIPPING
POWER GEN.
SAFETY can't be an afterthought
PROPER STORAGE SAVES LIVES!
NH_3
C_2H_6O
CH_3OH
CH_2O_2
Alternative Liquid Fuels
WE MUST DEVELOP:
Green Synthesis
Carbon Capture
ALF Fuel Cells
UK Research and Innovation
Sarahberia

Ammonia and Alternative Liquid Fuels

Challenges	Potential project areas
13. Catalysts for ammonia cracking	Catalyst development for NH_3 -> H_2 cracking.
14. Electrolysis of ammonia for hydrogen production	Electro-catalysts for electrolysis of ammonia for hydrogen production
15. Ammonia release safety	Ammonia release safety modelling, including cryogenic ammonia release on water.
16. Reducing NOx emissions	Modelling the combustion conditions for reduced NOx emissions.
17. Electrochemical synthesis of green ALFs	Efficient catalysts for electrochemical synthesis of ammonia and other ALFs.
18. Catalysts for green ammonia synthesis	Catalysts for green ammonia synthesis by conventional Haber-Bosch process.

Hydrogen End Use


UK-HyRES
END USE
REDUCE EMMISSIONS
HYDROGEN & ALTERNATIVE LIQUID FUELS
WHAT ARE OUR IMPACTS
WHERE CAN WE MAKE A DIFFERENCE?
HYDROGEN USED IN THE CHEMICAL, TRANSPORT AND HEATING INDUSTRIES
TODAY
55% OF HYDROGEN IS USED FOR AMMONIA PRODUCTION
HIGHER EFFICIENCY
LOWER EMMISIONS
HYDROGEN ENERGY
FUEL CELL TECHNOLOGIES ARE KEY
TECHNOLOGY
INDUSTRY
STANDARDISATION
GLOBAL COORDINATION & EDUCATION
NEED
ITS A CHICKEN AND EGG SCENARIO
PUBLIC OPINION: HYDROGEN SAFETY AND PERCEPTION
IS HYDROGEN A GREENHOUSE GAS LEAKAGE?
SUPPLY
COORDINATED SYSTEMS THINKING
HIGHER PROFILE OF HYDROGEN
FUNDING
SUPPORT & SKILLS
FOR CHANGE
COURSES
SPRINGBOARD FOR CHANGE
UTILISATION & TRANSPORTATION COMBINED
THE TRANSITION IS A CHALLENGE. ARE WE READY?
Scriberia

End Use

Challenges	Potential project areas
19. Reduction of iron oxide to steel with H_2	Direct reduction of iron oxide to steel with H_2.
20. Redesign of cement kilns	Redesign of cement kilns to reduce CO_2 emissions.
21. Burner improvement to reduce NOx	Improve H_2 and NH_3 burners to reduce NOx emissions.
22. Catalysts for hydrogen and ammonia combustion to reduce NOx	Develop suitable catalysts which can improve combustion of hydrogen and ammonia with reduced NOx emission

Cross-cutting	
23. H_2 as a GHG modelling	Modelling to understand the effects of H_2 as a green house gas.
24. Point-of-use purification	Develop point-of-use purification.

https://ukhyres.co.uk