Readiness of safety and environmental protection knowledge for a hydrogen energy economy

Technical + Innovation

energy institute

Dr Mark Scanlon CChem MEI

Head of HS&E Good Practice

Technical + Innovation

Energy Institute

Contents

Technical + Innovation

energy institute

- Energy Institute: overview
- Business overview for H2 as an energy carrier across the value chain, from production through to use, from the perspective of a collaborative industry organisation:
  - What does the future look like vs. H2 as an industrial gas?
  - What are the options and their readiness?
- Readiness of safety and environmental protection knowledge (research through to standards):
  - Knowns vs. unknowns
  - Who guards and is developing knowledge

Contents

- **Energy Institute: overview**
- Business overview for H2 as an energy carrier across the value chain, from production through to use, from the perspective of a collaborative industry organisation:
  - What does the future look like vs. H2 as an industrial gas?
  - What are the options and their readiness?
- Readiness of safety and environmental protection knowledge (research through to standards):
  - Knowns vs. unknowns
  - Who guards and is developing knowledge

EI overview

Technical + Innovation

energy institute

Our Purpose

The Energy Institute (EI) is the chartered professional membership body for people who work across the world of energy. We exist to create a better energy future for our members and society by accelerating a just global energy transition to net zero.

We do this in three ways

1. **Developing the future energy workforce**
2. **Bringing together expertise and advice**
3. Enabling lower carbon and safe energy

Engagement in the Technical + Innovation programme will help accelerate the energy transition through member collaboration, dialogue with regulators, academia and wider stakeholders.

You will benefit from access to a wide range of standards and good practice materials to ensure industry operations are sustainable, efficient and safe.

In numbers

Technical + Innovation

energy institute

One

single dedicated team supporting the global energy industry

A portfolio of

750+

titles, with 100,000+ wider industry resources via the EI Knowledge Service

120

countries in which Technical Partners and Technical Company members are using EI technical content

60+

technical publications issued each year, more than one per week

Funding

$2.5M

in technical research every year

1,000+

industry representatives

More than

65,000

users of our Toolbox Safety App each year – once every two minutes

60+

Technical Partners and Technical Company Members

Technical Partners and Technical Company Members

Technical + Innovation

energy institute

ADNOC	AIRBUS	ASTRON ENERGY	Bapco Refining	Basra Energy	BCECA	BOEING	bp	Chevron	CNOOC
CONIDIA	CORIO	DCC	drax	EDF renewables	eni	equinor	ESSAR ENERGY	exolum	ExxonMobil
Harbour Energy		ITHACA ENERGY	KBR	MARATHON	NEPTUNE ENERGY	NESTE	OMV	Ørsted	OW OCEAN WINDS
petroineos	PHILLIPS 66	PRAX	QatarEnergy	Q8	RAS	REPSOL	Rio Tinto	RWE	saudi aramco
SCOTTISHPOWER	SGS		SIEMENS Gamesa	SPIRIT ENERGY	sse Renewables	sse Thermal	TAQA	TotalEnergies	TSG
TÜVRheinland	uniper	VALERO	VATTENFALL	Vitol	woodside	World Fuel Services			

We collaborate with

At a glance

Technical + Innovation

energy institute

The Technical + Innovation work programme can be broadly split into three overlapping areas:

The energy transition

Carbon capture, utilisation and storage

Hydrogen

Power systems

Offshore wind

Onshore wind

Health, safety and environment

Health

Human and organisational factors

Process safety

Asset integrity and life extension

Environment and sustainability

Fuel quality and management

Aviation fuel handling

Fuels distribution

Hydrocarbon management

Test methods standardisation

Leading on hydrogen

Also working on hydrogen as well as other topics

Contents

Technical + Innovation

energy institute

- Energy Institute: overview
- **Business overview for H2 as an energy carrier across the value chain, from production through to use, from the perspective of a collaborative industry organisation:**
  - **What does the future look like vs. H2 as an industrial gas?**
  - **What are the options and their readiness?**
- Readiness of safety and environmental protection knowledge (research through to standards):
  - Knowns vs. unknowns
  - Who guards and is developing knowledge

Wider context

Technical + Innovation

energy institute

Net zero emissions (NZE) by (e.g.) 2050 target:

- Nations and organisations responding
- Energy system paradigm shift required in 25 years
- Rethink and deliver – generate, store, transmit, distribute and use energy
  - Comparison to first industrial revolution – 100 years
  - Incremental changes in last 25 years in energy: LNG, shale gas, biofuels, electrification, decommissioning – massive change expected
  - Some technologies will be winners; others not, maybe multiple solutions until system stabilises
  - Policy uncertainty
- Lots of H2 projects announced; only some have passed FID and have offtake markets
- Maintain existing assets
- Simultaneously address climate change (Natechs etc)
- Deliver H2 energy system at ramped up scale

! Operate within uncertainty

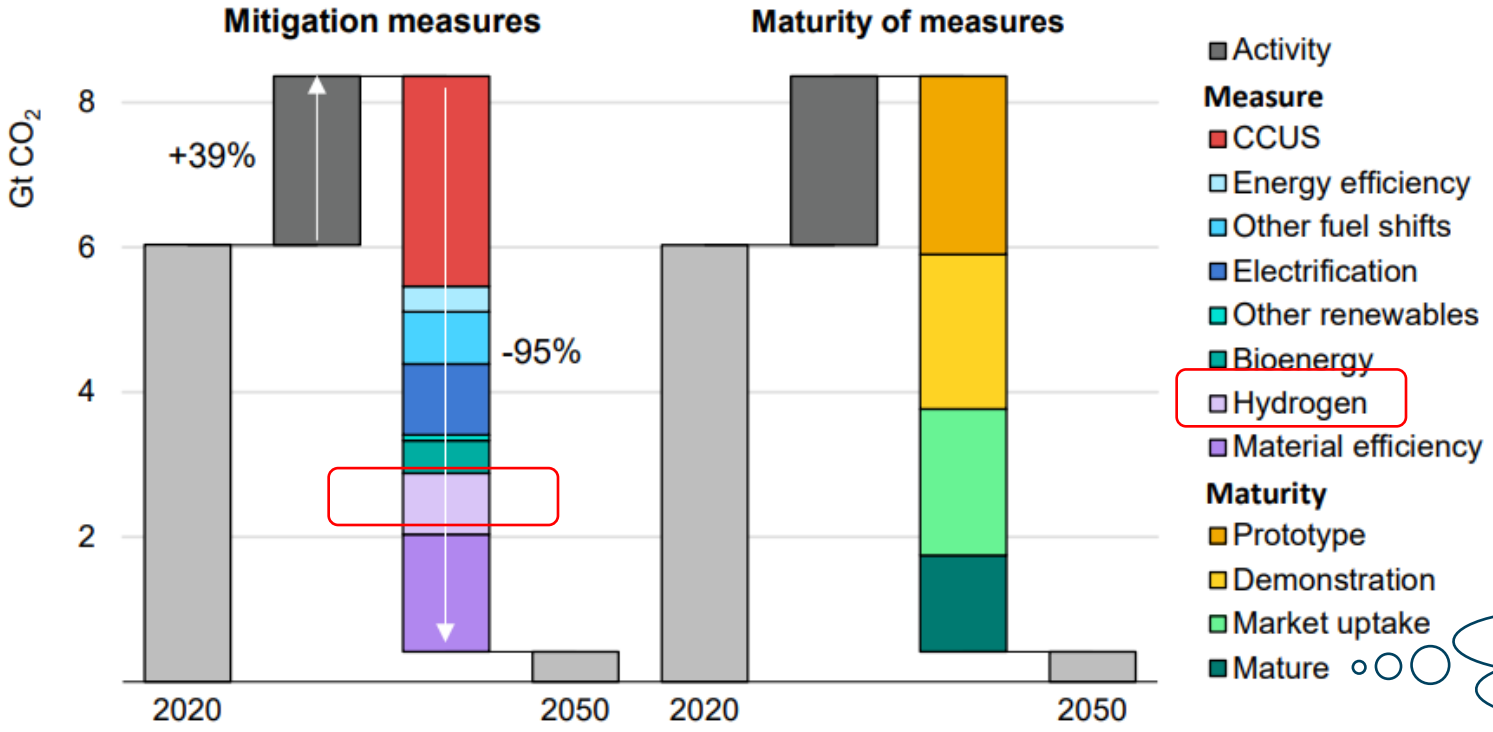
! Asset integrity/PS leadership

Example decarbonization options – heavy industries (e.g. steel and cement manufacture) in G7

Technical + Innovation

energy institute

Figure 1.6 Global direct CO_2 emissions reductions in heavy industries by mitigation measure and current technology maturity category in the Net Zero Emissions by 2050 Scenario

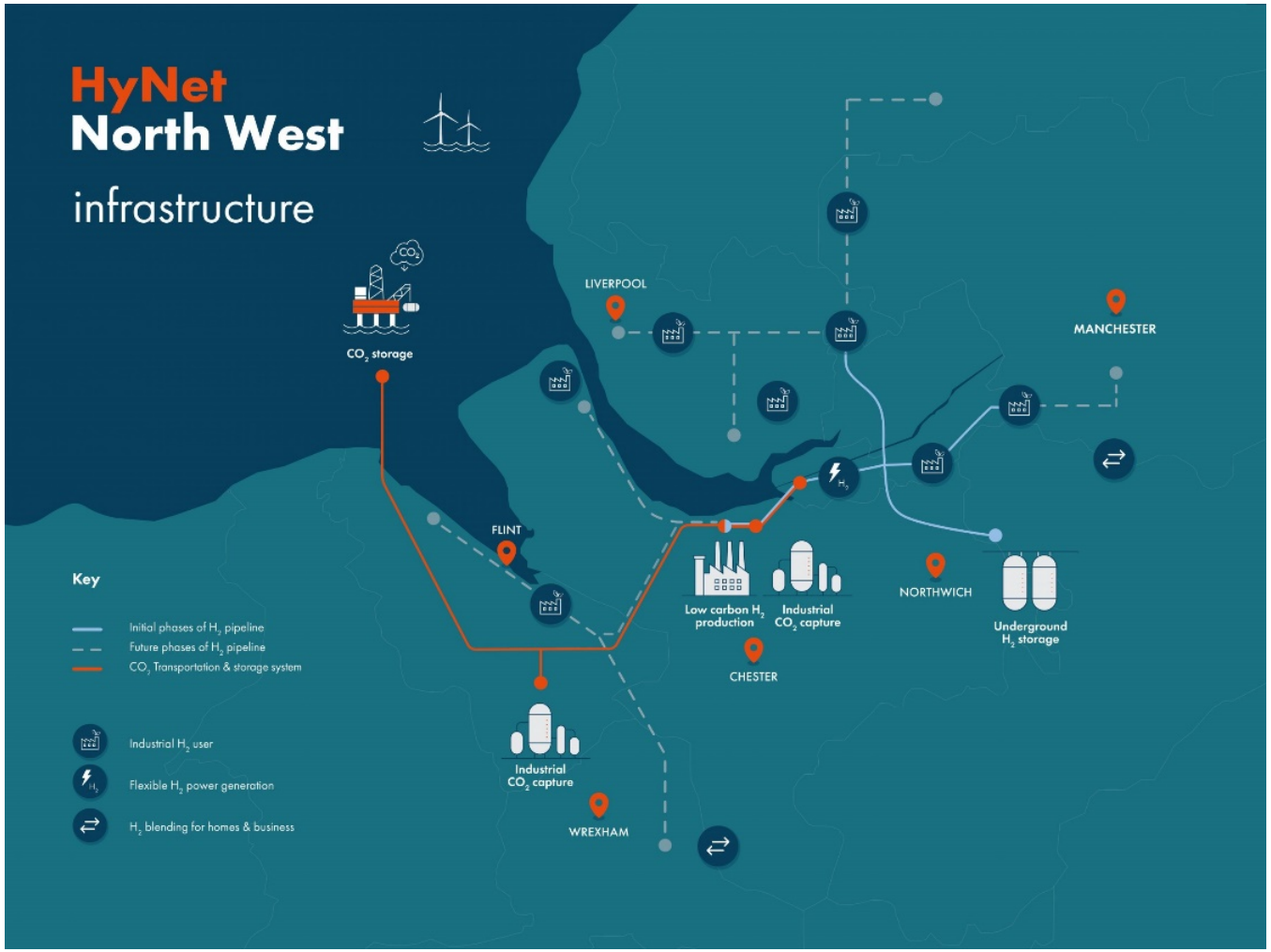


! Multiple technologies required – benign plants become MAH sites, several hazards?

But only some technologies mature – iterative deployment over decades?

IEA (2022), Achieving net zero heavy industry sectors in G7 members, IEA, Paris https://www.iea.org/reports/achieving-net-zero-heavy-industry-sectors-in-g7-members, Licence: CC BY 4.0

Example decarbonization options – cluster integration and build out from clusters



Courtesy: HyNet https://hynet.co.uk

Technical + Innovation

energy institute

TÜV Rheinland Process Safety Management Workshop and Conference ‘What is Process Safety Leadership’s role in managing risk during the transition to net zero?’ (Edinburgh, November 2023):

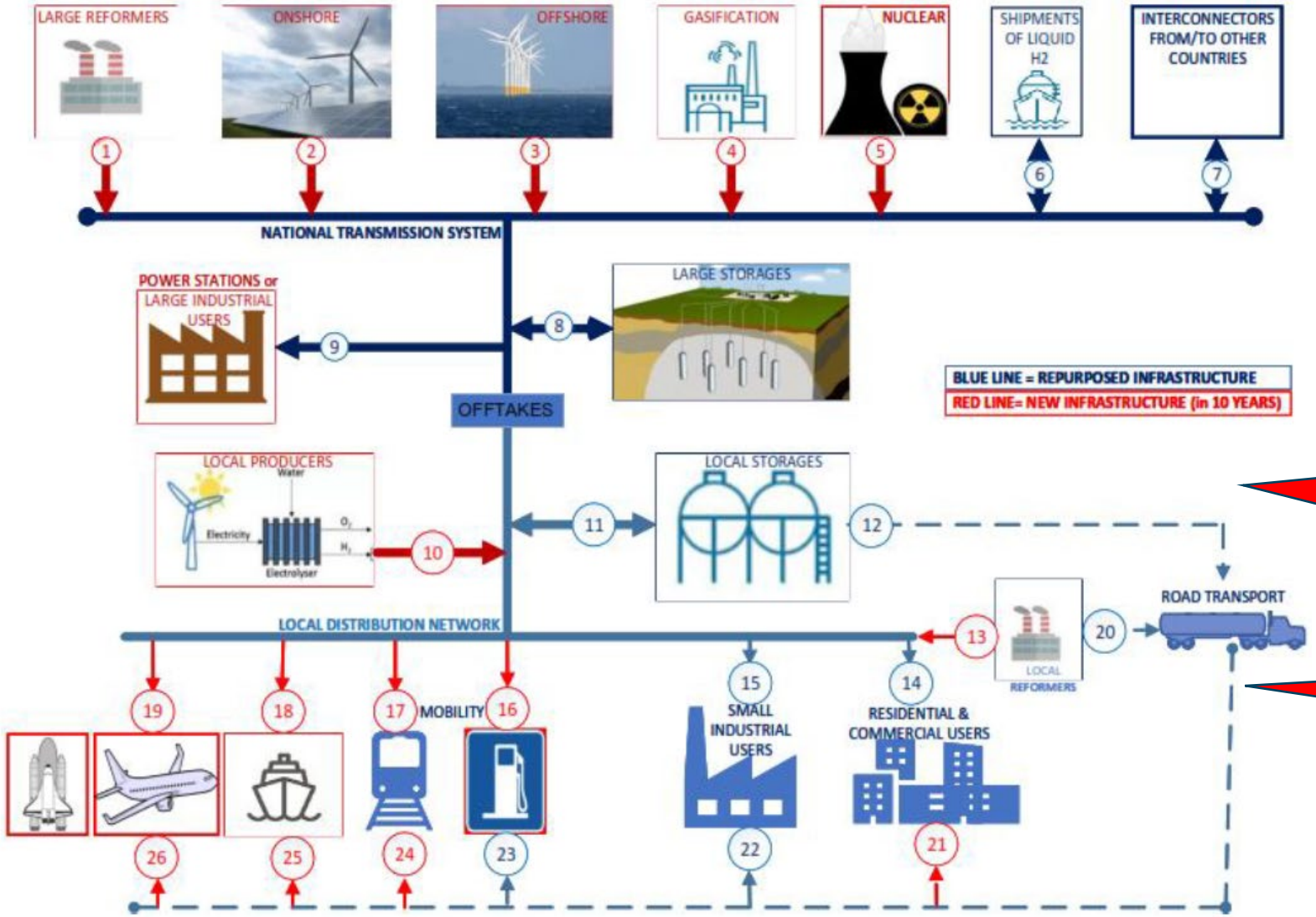
- Multi-site hazard study development (interfaces in clusters)
- Innovative technology engineering controls
- Ensuring new companies use guidance

! Several PS issues

Hydrogen value chain –national systems view

Technical + Innovation

energy institute



H2 energy value chain more complex, more interfaces than H2 industrial gases value chain. Also, simpler value chain without pipelines, and another for LH2

We need to take a systems view, consider interfaces, as well as considering each value chain block

! New interfaces, new operators, new operations
EU Hydrogen backbone ~130 MTe H2 in pipeline network

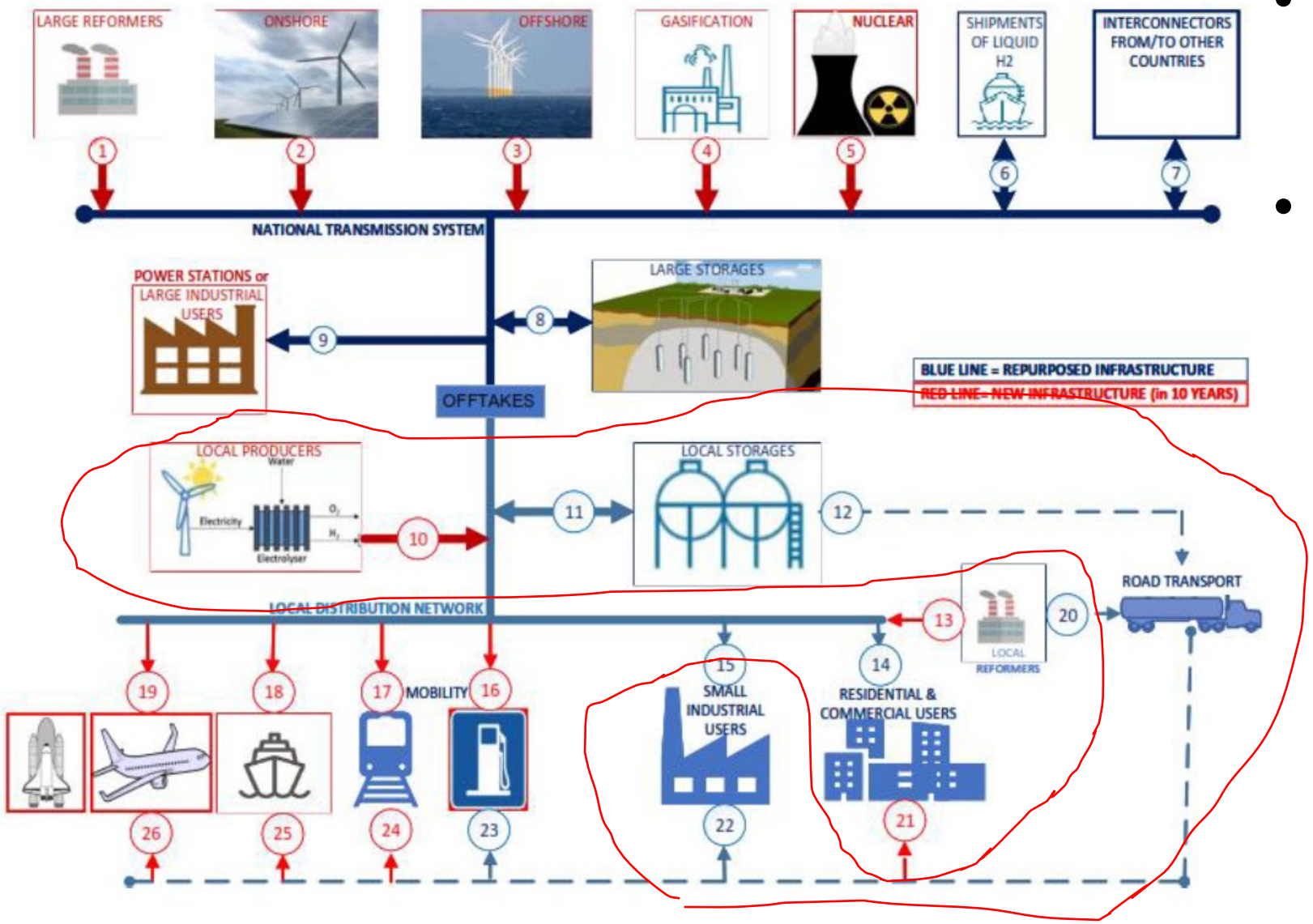
! Graphic excludes some options, e.g. gold H2 (natural subsurface)

From EI *Research Report: Hydrogen value-chain infrastructure integration: Interface analysis landscape review*

Simple hydrogen value chain – simpler local cluster

Technical + Innovation

energy institute



- Phase 1 'General Interface Assessment' identified issues around custody transfer compared to NG network operation
- Phase 2a (2025): Technology Maturity & Service Supply Chain Summary: Investigate key areas of weakness in elements of technology and service interfaces, e.g. infrastructural technology/ hardware related services, isolation systems, pressure reducing systems with overpressure protection, leak detection/gas detectors, etc.

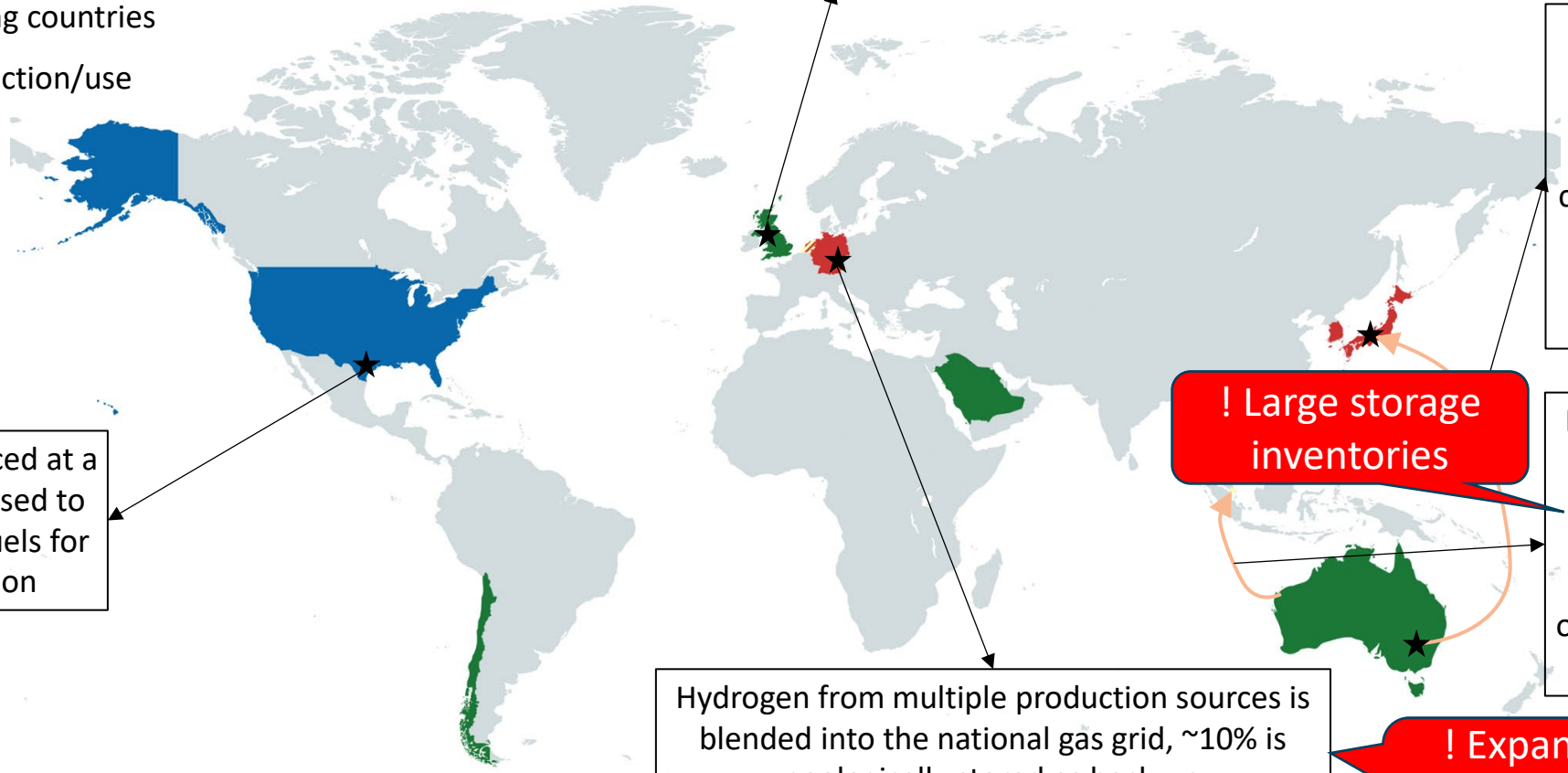
! Knowledge gaps with some safety systems

Various forms and configurations of hydrogen transportation and storage infrastructure will be needed to link areas of production to demand

The majority of hydrogen is expected to be produced and used locally, however 20-50% could be transported internationally.

***Example* global hydrogen transport routes**

- Net H_2 exporting countries
- Net H_2 importing countries
- Balanced production/use



Hydrogen is produced and consumed within a cluster of nearby industries

! Global shipping of H2 or LOHCs

Hydrogen is produced in a region with low-cost, low-carbon electricity and shipped as ammonia to a country which may not have capacity to produce the amount of hydrogen required domestically

Hydrogen is produced at a refinery site and used to manufacture synfuels for shipping/aviation

! Large storage inventories

Hydrogen is expected to be exported via trading hubs which have significant storage capacities and are strategically located for onwards shipping/ transport

Hydrogen from multiple production sources is blended into the national gas grid, ~10% is geologically stored as back-up

! Expanded number of salt caverns or sandstone etc storage

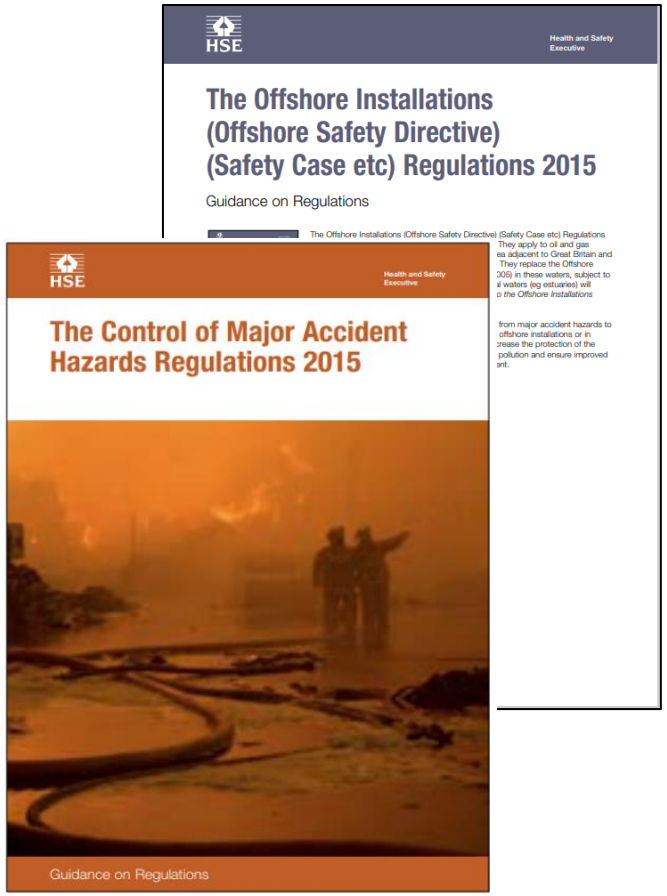
Safety cases, on- and offshore – applicability of legislation etc

Technical + Innovation

energy institute

- Offshore Safety Directive/SCR 2015 does not cover offshore hydrogen production but can be followed as a general framework for managing hazardous fluids
- Seveso Directive/COMAH Regulations apply to hydrogen (and associated substances, e.g. LOHC) for onshore facilities
- From EI *Research report: Review of directives/regulations relevant to the safe and environmentally compliant production, transportation and storage of hydrogen*

! Scope gaps with some legislation, etc (but general duties may suffice)



Ocean REFuel research programme

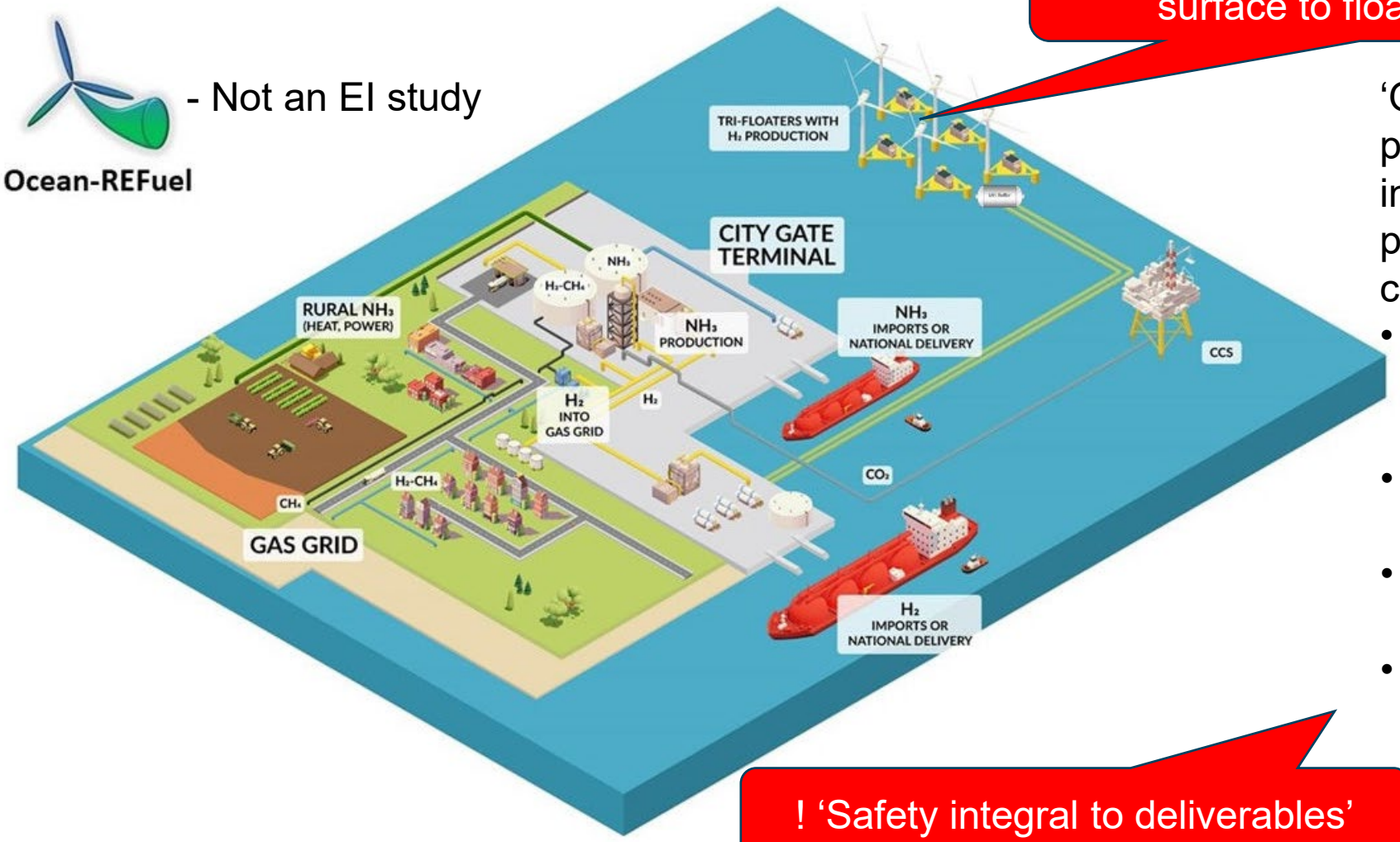
Technical + Innovation

energy institute

Ocean-REFuel

- Not an EI study

! Local electrolysers and H2 storage sub-surface to floating wind tripods



! ‘Safety integral to deliverables’

‘Ocean REFuel programme will produce a blueprint for the first integrated ocean renewable fuel production facility.’ Research comprises:

- Simulating intermittent operation of electrolysers for local offshore H2 production
- Simulating metocean conditions on electrolyser operation
- Testing seawater vs. desalinated water for electrolyser feedstock
- Land-based NH3 production for national export (investigating LCA benefits)

Contents

Technical + Innovation

energy institute

- Energy Institute: overview
- Business overview for H2 as an energy carrier across the value chain, from production through to use, from the perspective of a collaborative industry organisation:
  - What does the future look like vs. H2 as an industrial gas?
  - What are the options and their readiness?
- **Readiness of safety and environmental protection knowledge (research through to standards):**
  - **Knowns vs. unknowns**
  - **Who guards and is developing knowledge**

EI hydrogen programme

Technical + Innovation

energy institute

Understanding and addressing technical challenges for the deployment of a hydrogen economy

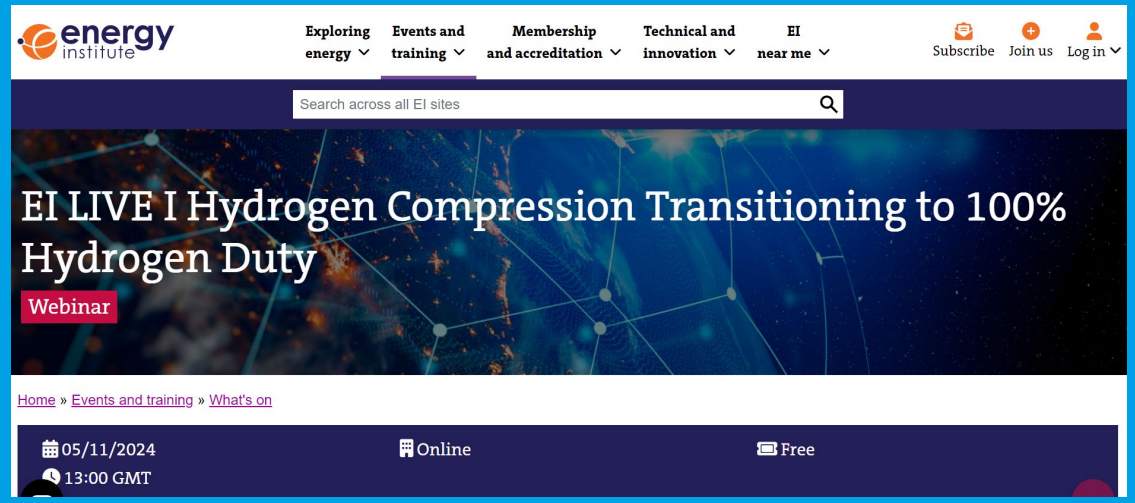
Options to decarbonise the energy system include hydrogen and its derivatives (e.g., ammonia) as energy carriers. Our hydrogen work programme considers the value chain from the various means of hydrogen production through to its different uses.

We focus on independent technical and techno-economic research and good practice development. We bring together global operating companies, policy-makers, regulators, consultancies, service providers, academia, trade associations and like-minded stakeholder organisations.

The work programme covers process safety, asset integrity, environmental assessment (lifecycle analysis), plant design (e.g., filling stations), quality determination (e.g., fuel cell quality) and quantity determination.

How we work:

- Stakeholder engagement, including collaborative funded projects
- Input workshops
- Publications (reports, guidelines, etc)
- Conference presentations
- Output dissemination workshops, webinars – e.g.:

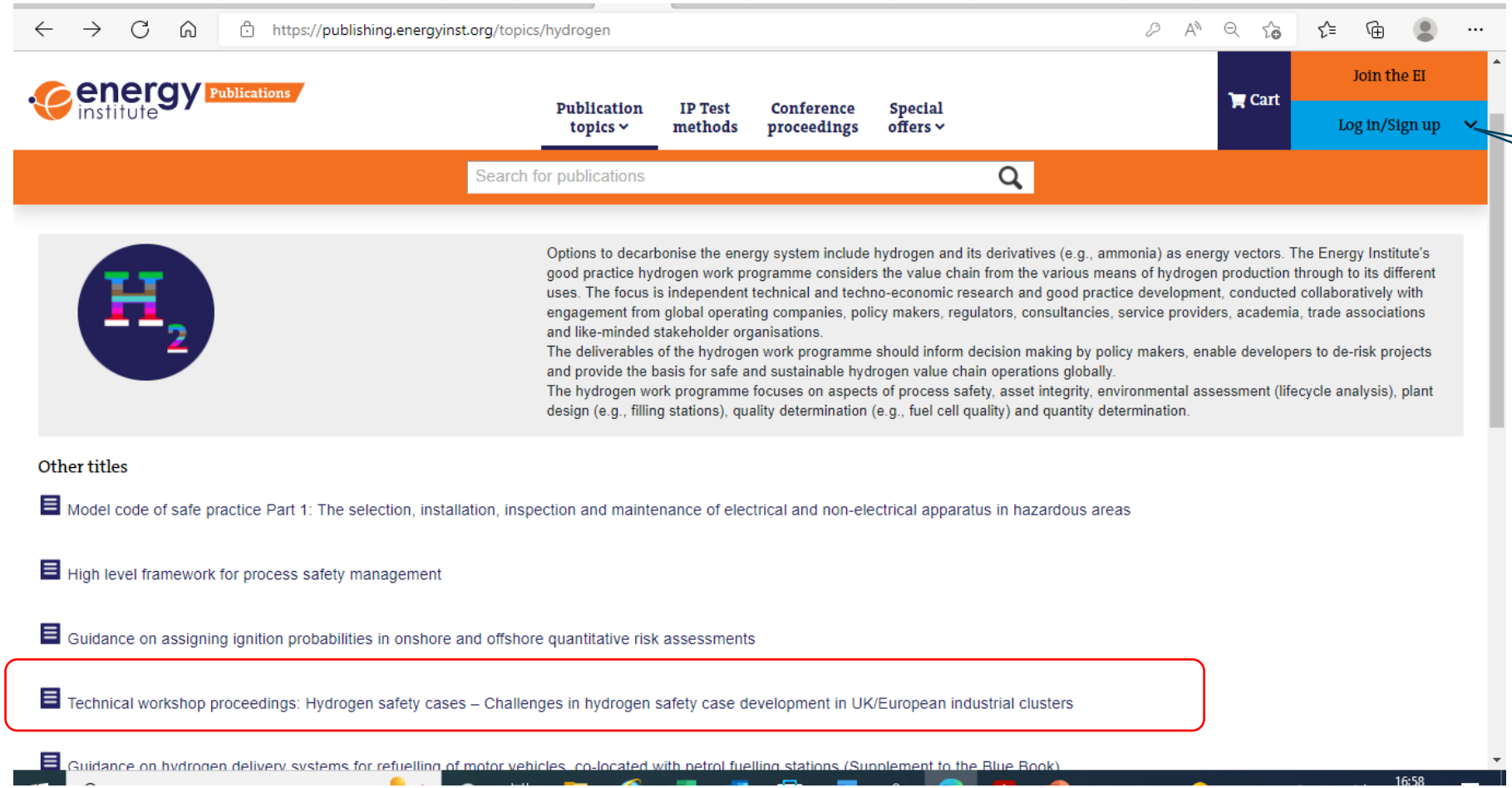


Accessing EI Publications (reports, guidelines, etc)

Technical + Innovation

energy institute

https://publishing.energyinst.org/



Some regulators have a *gratis* publications licence (e.g. HSE, NOPSEMA, RIVM) – available to others on request

Timeline for EI hydrogen knowledge development up to mid-2023

Technical + Innovation

energy institute

Define | Develop | Deliver

- End 2018 Council request - Decarbonise
- January 2019 Inaugural energy transition stakeholder workshop
- October 2019 CCUS, Hydrogen, Power Systems stakeholder workshops
- January 2020 Hydrogen stakeholder meeting
- November 2020 Inaugural Hydrogen Committee meeting
- Jan 2021 funding allocated to six Phase 1 gap analysis H2 projects
- April 2021 Safety cases workshop (in pandemic)
- Nov 2021 Published Technical workshop proceedings: Hydrogen safety cases

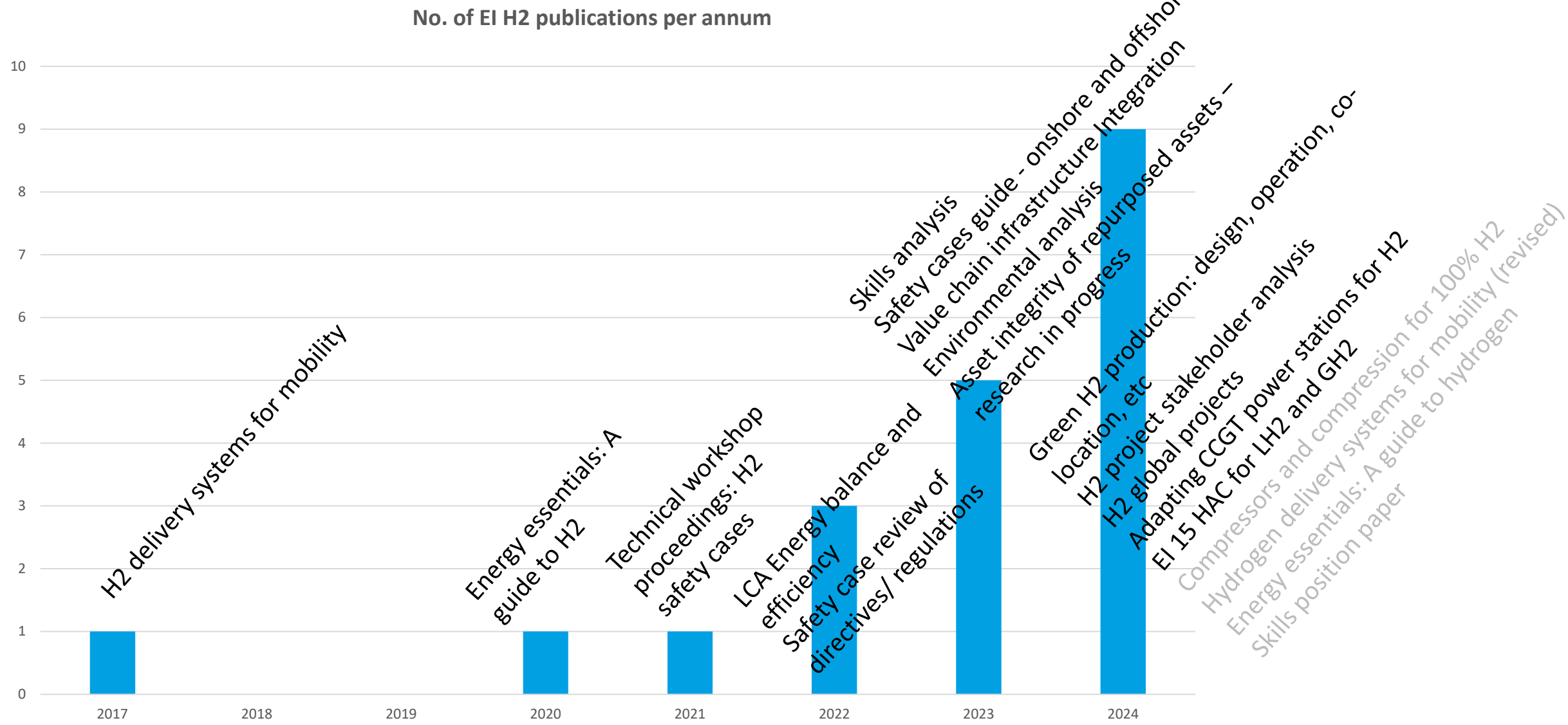
Define | Deliver | Define | Deliver | Define | Deliver

- Jan 2022 New project funding
- April 2022 Published Asset integrity of repurposed assets
- May 2022 Published LCA Energy balance and efficiency
- Oct 2022 Published Safety case review of directives/ regulations
- Jan 2023 New project funding
- May 2023 Published skills analysis
- May 2023 Published safety cases guide
- June 2023 Define 2024 work programme
- July/Aug 2023 Published Infrastructure Integration and Env analysis

Etc.

Cavern storage wellhead.
Courtesy SABIC

EI knowledge development output (2024 grey titles 'in press')



Understanding and addressing technical challenges for the deployment of a hydrogen economy

Technical + Innovation

energy institute

Key highlights 2023

- Published guidance on developing a safety case for hydrogen in the UK, which seeks to provide clarity on compliance with existing legislation, fill knowledge gaps and provide examples of developing the safety case for real world projects, both onshore and offshore. This work has been presented widely.
- Published a research report on hydrogen value-chain infrastructure integration, which outlines findings from interviews conducted with different stakeholders regarding 26 hydrogen infrastructure interfaces, addressing associated concerns and challenges.
- Hosted a workshop on hydrogen competency and skills, bringing together stakeholders to understand the challenges facing industry, and to determine the EI's role in addressing these challenges.
- Hosted a workshop to convene and engage stakeholders and discuss the key issues around the development of a national energy storage network for hydrogen and liquid derivatives (LH2, NH3, LOHC, MCH).

Safety cases

Skills and competency

Infrastructure integration

Storage

! Implicitly, all these areas are knowledge shortfalls, until resolved

Understanding and addressing technical challenges for the deployment of a hydrogen economy

Technical + Innovation

energy institute

2024 programme includes:

Asset integrity

- Developing guidelines on the asset integrity management of change to enable repurposing of NG networks to H2 or H2/NG blends.
- Providing clear and quantitative risk-based guidance for determining safe separation distances associated with H2 storage and dispensing equipment, and the potential impact on surrounding activities. Complements IEA study for larger installations.

QRA data

- Supporting the SafeN JIP on H2 and NH3 (and CO2) loss of containment data availability for QRAs.
- Continuing to undertake research on large scale storage of H2 (and LOHCs).

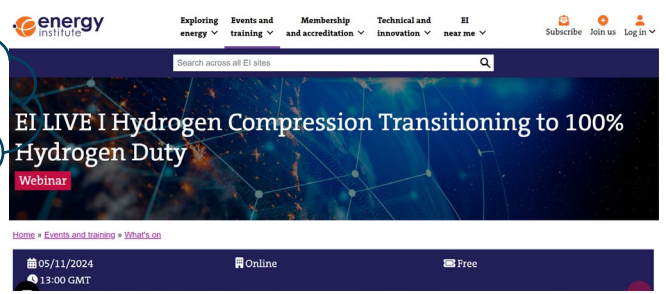
Separation distances

Skills and competency

- Drafting a position paper on the development of competence, skills and training for the transition to a H2 economy.

Marine fuels

- Literature review on HSSE for NH3 (and MeOH) marine fuels (workshop 15 October 2024)
- Completing research on compression systems for 100% hydrogen operation (webinar 5 November 2024). Report 'in press'.



! Anecdotally, knowledge on compression systems poorly understood

Compression

Understanding and addressing technical challenges for the deployment of a hydrogen economy

Technical + Innovation

energy institute

2025 *provisional* programme includes:

- Continuing to undertake research on large scale storage of H2 (and LOHCs).
- Developing guidance on the management of corrosion and wider asset integrity management of facilities handling hydrogen.
- Literature review of requirements for the design and construction of road tankers for the transport of GH2 and LH2 and NH3
- H2 Information Management Portal – Phase 1: Legislation, Regulations and Standards module
- Transition technologies (including H2) animation
- Evaluating the energy balance and efficiency of a whole hydrogen-derivative energy system, from production to consumption
- Infrastructure Integration – Phase 2 Technology Maturity Assessment for H2 and H2/NG blends, e.g. infrastructural technology/ hardware related services, isolation systems, pressure reducing systems with overpressure protection, leak detection/gas detectors, etc.
- NH3 process safety from production to end use in the emerging NH3 energy economy
- Process safety challenges in managing change when introducing low carbon technologies (including H2) to existing facilities

Road tankers

LCA

NH3 PS

Information management

PS MoC

Corrosion management

Stakeholder 'explainer'

Infrastructure integration

Wider adaptation of EI publications for the energy transition:

Technical + Innovation

energy institute

EI has a portfolio of existing process safety standards (~75 No.), as well as for asset integrity and human factors

~50 No. process safety standards generic or reports – no amendment required for energy transition

Other 25 No. being adapted for energy transition. E.g., in process safety portfolio:

- EI 3015 ('EI 15'): hazardous area classification, now includes GH2 and LH2 – previously only 'refinery' H2
- EI 3314: PFP for BESSs, MoC for PFP suitability for low carbon fuels, including H2

But significant effort to revise all pertinent standards, and not all required research complete before codifying

! Operate within uncertainty

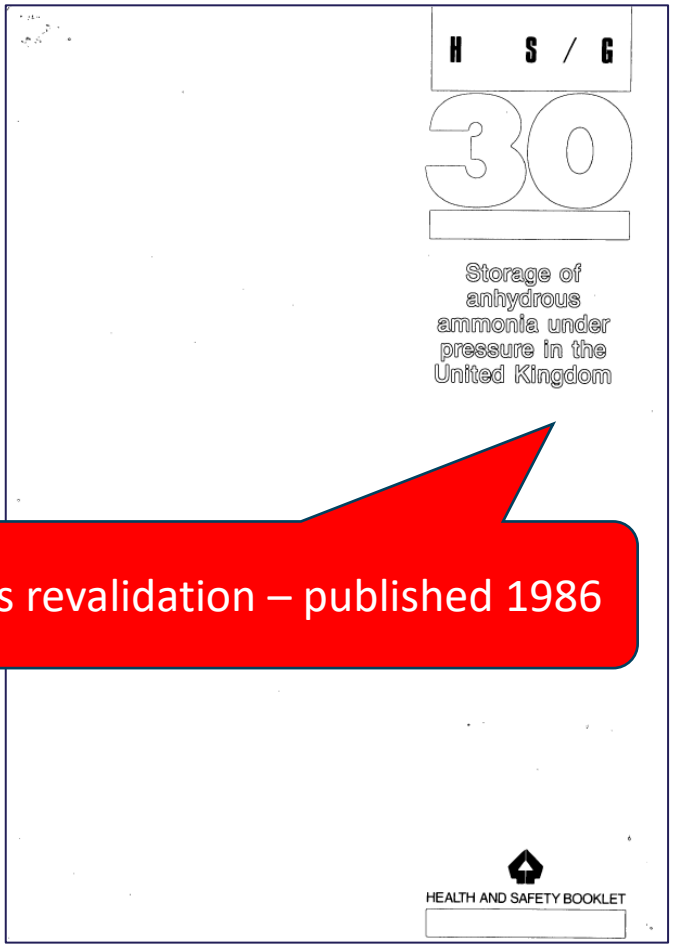
Who guards and is developing knowledge

Technical + Innovation

energy institute

A complex picture, with multiple organisations working in parallel and lacking high-level coordination. Some operate at different TRLs. They includes:

- Research councils, regulators (e.g. OFGEM) and governmental funding applied mainly to academia, academia hubs (e.g. Ocean RE-Fuel, IDRIC, Mari-NH3), consultancies and technology developers (e.g. Net Zero Technology Centre)
- Trade associations (H2 Council, EIGA, EEMUA, BCGA)
- Professional bodies (IGEM, EI)
- Standards Development Organisations (e.g. ISO TC/197 and TC/67)
- IEA for HAC and separation distances
- Skills bodies (e.g. Cogent, E&U Skills, ECITB, Opito)



Contents

Technical + Innovation

energy institute

- Energy Institute: overview
- Business overview for H2 as an energy carrier across the value chain, from production through to use, from the perspective of a collaborative industry organisation:
  - What does the future look like vs. H2 as an industrial gas?
  - What are the options and their readiness?
- Readiness of safety and environmental protection knowledge (research through to standards):
  - Knowns vs. unknowns
  - Who guards and is developing knowledge

Readiness of safety and environmental protection knowledge for a hydrogen energy economy

Technical + Innovation

energy institute

Dr Mark Scanlon CChem MEI

Head of HS&E Good Practice

Technical + Innovation

Energy Institute

mscanlon@energyinst.org

+44 7795 272934