

CCUS safety: guidance and research landscape

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Introduction to the Health and Safety Executive

- HSE is the regulator for workplace health and safety in Great Britain
 - Includes onshore/offshore pipelines, chemical/oil/gas infrastructure, offshore platforms etc.
 - Activities: evidence gathering, policy development, consultation, regulation, incident investigation, enforcement
 - 3,000 total staff (FTE): £310M annual budget, 66% from Government*
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- HSE Science and Research Centre, Buxton, UK
 - 400 staff, 550-acre test site
 - Scientific support to HSE and other Government departments
 - “Shared research” or joint-industry projects co-funded by HSE
 - Bespoke consultancy on a commercial basis



* <https://www.gov.uk/government/publications/the-health-and-safety-executive-annual-report-and-accounts-2024-to-2025>

HSE Areas of Research Interest



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Reduce work-related ill health, with a specific focus on mental health and stress	7
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Increase and maintain trust to ensure people feel safe where they live, where they work, and in their environment	11
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Enable industry to innovate safely to prevent major incidents, supporting the move to net zero	15
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HSE Areas of Research Interest

Question 1: How can it be ensured that GB's evolving industrial landscape and the built environment doesn't lead to a higher likelihood of major health and safety incidents?

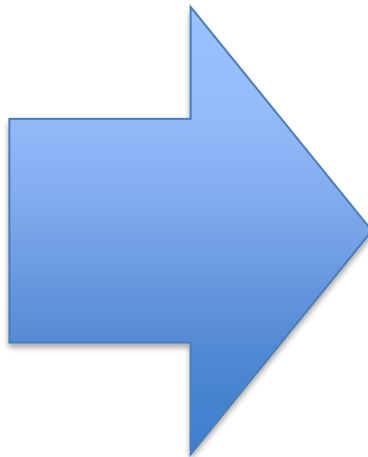
- What are the significant hazards and risks associated with the deployment and scale-up of new and emerging technologies for Net Zero, such as Carbon Capture Usage and Storage (CCUS) and hydrogen?
- What research is needed to support new industries such as CCUS, hydrogen etc., to ensure that the risks to workers and the public are kept as low as reasonably practicable?
- What are the appropriate controls and mitigations that need to be built into new carbon capture infrastructure?
- How do operational fusion power plants compare in risk profile to more traditional industrial installations?
- How can the integrity and safety of industrial assets be ensured across their lifecycle?

<https://www.hse.gov.uk/research/assets/docs/hse-areas-of-research-interest.pdf>

<https://ari.org.uk/>

HSE Areas of Research Interest

- What are the new hazards and risks?
- Do the locations of new technologies pose hazards and risks?
- What lessons can be learnt from traditional industries, and from early adopters?
- Issues with retrofitting and repurposing?
- Impacts of climate change?



- New and emerging technologies for Net Zero
- | | |
|--------------------|-----------------------------|
| Hydrogen | Renewables |
| CCUS | Fusion |
| | Energy storage |
| Industrial assets | Electrical infrastructure |
| Novel materials | New manufacturing processes |
| Low-carbon heating | Electric vehicles |
| Climate adaptation | |

CCUS safety: guidance and research landscape

**Process control and
asset integrity**

**System design and
operation**

Loss of containment



There are many ways to cut up a pie...

CCUS safety: guidance and research landscape

Process control and asset integrity	System design and operation	Loss of containment
Choice of CO ₂ specification	CO ₂ capture	Failure modes and frequencies
Measurement of impurities	CO ₂ pipelines (including repurposing)	Hazard and risk analysis
Flow assurance and EOS	Ship transport of CO ₂	Health effects
Reaction chemistry	Rail transport of CO ₂	Emergency response
Materials selection: corrosion, embrittlement and fracture	Intermediate CO ₂ storage	
Monitoring, inspection and NDT	Wells and CO ₂ injection	

Process control and asset integrity (1 of 2)

Choice of CO₂ specification

- Wood [CO₂ Specification JIP](#)
- DNV [CO₂SpecChain](#)
- SINTEF [IMPACTS](#)
- ISO TC/265 [PD ISO/TR 27921](#)

Measurement of impurities

- DNV [CO₂MET](#)
- Energy Institute [EI 3589](#)
- Force Tech. [measurements](#)
- Force Tech. [calibration gases](#)
- **NPL?**

Flow assurance and equations of state

- Wood [CO₂ Specification JIP](#)
- Energy Institute [EI 3518](#)
- IFE [CO2Fact2](#)
- SINTEF [ImpreCCS](#)
- SINTEF [DeFACTO](#)
- ISO TC/265 [ISO/TR 27925](#)

Reaction chemistry

- Wood [CO₂ Specification JIP](#)
- TWI [ENCO₂RE](#)
- DNV [CO₂RE](#)
- IFE [ALIGN-CCUS](#)
- IFE [KDC-IV](#)

Process control and asset integrity (2 of 2)

Materials selection: metallics

- **Wood** [CO₂ Specification JIP](#)
- **PRCI** Embrittlement and crack enlargement
- **PRCI** Hydrogen in CO₂ stream
- **DNV** [CO₂SafePipe](#)
- **DNV** [Materials performance in CO₂ wells](#)
- **DNV** [CO/CO₂ cracking](#)
- **DNV** [Safe and sour](#)
- **IFE** [KDC-IV](#)
- **IFE** [CO₂WELLMAT](#)
- **TWI** [MASCO₂T](#)
- **TWI** [MASCO₂T II](#)
- **TWI** [MARCO₂](#)
- **Leeds Univ. / Wood** [Impure CO₂ transport*](#)
- **HSE** [CROSS](#)

* proposed

Materials selection: polymers

- **Wood** [CO₂ Specification JIP](#)
- **DNV** [CO₂SafePipe Polymers](#)
- **SINTEF** [CO₂ EPOC](#)
- **TWI** [Thermosets JIP](#)
- **TWI** [Thermoplastics JIP](#)

Monitoring, inspection and NDT

- **API** [RP 1192](#)
- **DNV** [RP F104](#)
- **ISO TC/265** [ISO 27913](#) Annex E
- **ROSEN** [paper](#)
- Further work needed, e.g., EMAT for thick-walled CO₂ pipelines?
- Equivalent to [POF 520](#) for CO₂?

System design and operation (1 of 2)

CO₂ capture

- TCM [Mongstad operations](#)
- SINTEF [SOLVit](#)
- ISO TC/265 [ISO/TR 27922](#)
- Global CCS Institute: [CCS Technologies](#)

Shipping

- ZEP/CCSA [Shipping guidance](#)
- DNV [CETO](#)
- SINTEF [CO2LOS](#)
- ISO TC/265 [ISO/TR 27929](#)

Pipelines

- ISO TC/265 [ISO 27913](#) (also CEN [TC/474](#))
- API [RP 1192](#)
- DNV [RP F104](#)
- DNV [CO₂SafePipe Phase 2](#)
- DNV [Flexible Composite Pipes](#)
- CEN [prCEN/TR 18404](#) polymer/composite pipes
- DNV [Tensile Armor Wires](#)
- Energy Institute [EI 3554](#)
- Energy Institute [EI 3545](#)
- IOGP [Re-Stream](#)
- Is work needed on **in-service repairs** on CO₂ pipelines to complement [National Grid/COOLTRANS](#) and API [RP 1192](#)?

System design and operation (2 of 2)

Rail

- DNV [CO₂ on Track](#)

Intermediate storage

- DNV [CO₂RISKMAN](#)
- DNV [CETO](#)
- Energy Institute [EI 3553](#)
- Energy Institute [EI 3554](#)
- SINTEF [CO₂LOS](#)
- ISO TC/265 [ISO/TR 27929](#)
- HSE/DNV/SINTEF/USN [CO₂BLEVE*](#)

Wells and CO₂ injection

- ISO TC/265 [ISO/TR 27923](#)
- DNV [CO₂ Offshore injection](#)
- SINTEF [CO₂FFER](#)
- SINTEF [RETURN](#)
- SINTEF [IntoWell](#)
- SINTEF [PorePac](#)
- IFE [Cementegrity](#)
- IFE [SFI SWIPA](#)
- Noble [CO₂ Drilling System](#)
- IOGP Reports [665](#) and [665-1](#)
- API [Bulletin 5100](#)

* proposed

Loss of Containment

Failure modes and frequencies

- Safetec [SAFEN](#)

Health effects

- IOGP [Report 443-14](#)
- HSE [Toxicity of chemicals](#)
- Further work needed on neurological effects and impairment with CO₂?

Emergency response

- API [Tactical guidance](#)
- DNV [CO₂RISKMAN](#)
- DNV [Skylark](#)
- Energy Institute [EI 3553](#)
- Further work needed on offshore emergency response?

Hazard and risk analysis

- DNV [CO₂RISKMAN](#)
- DNV [Skylark](#)
- DNV [SubCO₂ Phase 3*](#)
- DNV [KFX for CO₂](#)
- National Gas / DNV [FutureGrid CO₂](#)
- Energy Institute [EI 3553](#)
- ConcenCUS [Deliverable 8.6](#)
- IOGP [Report 670](#)
- SINTEF [IntoCloud](#)
- SINTEF [CO₂ Dynamics](#)
- SINTEF [SAFE_{CO₂}/DACOLLS](#)
- HSE [CROSS](#)
- HSE/DNV/SINTEF/USN [CO₂BLEVE*](#)

* proposed

Summary

- Much research has been done, but many areas of ongoing active work:
 - In particular: reaction chemistry, corrosion, fracture, dispersion
- Several proposed research projects at proposal stage, needing funding
 - DNV SubCO₂ underwater releases, CO₂ BLEVEs, Leeds Univ/Wood corrosion
- Research and guidance in some areas appears limited, although knowledge may exist in-house:
 - In-service repairs of CO₂ pipelines?
 - Inline inspection of thick-walled CO₂ pipelines?
 - Corrosion monitoring and inspection of process plant?
 - Offshore emergency response?

**If you know of any further guidance and research on these topics,
please do not hesitate to get in touch**

Thank you

Any questions?

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- Disclaimer: the contents of this presentation, including any opinions and/or conclusions expressed, are those of the authors alone and do not necessarily reflect HSE policy
- To review HSE areas of research interest, search here: <https://ari.org.uk/> or <https://int.octopus.ac/>